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Elk and Domestic Sheep Interactions in a North-Central Utah Aspen Ecosystem

Jeffrey L. Beck
Jerran T. Flinders
Deanna R. Nelson
Craig L. Clyde
H. Duane Smith
Perry J. Hardin

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The Authors

Jeffrey L. Beck is a Lands Biologist with the Southeastern Region, Utah Division of Wildlife Resources, Price, UT. He was a Graduate Research Assistant in the Department of Botany and Range Science at Brigham Young University, Provo, UT. He holds Bachelor (1993) and Master of Science (1996) degrees in wildlife and range resources from Brigham Young University. He is certified as an Associate Wildlife Biologist with The Wildlife Society.

Jerran T. Flinders is a Professor of Wildlife and Range Resources in the Department of Botany and Range Science at Brigham Young University, Provo, UT. He has Bachelor (1967) and Master of Science (1968) degrees in zoology from the University of Utah and a Ph.D. degree in range science (1971) from Colorado State University. He is a Certified Wildlife Biologist with The Wildlife Society.

Deanna R. Nelson is an Ecologist for the Uinta National Forest, Provo, UT. She holds a Bachelor of Arts degree (1982) in biology from Doane College, Crete, NE, and a Master of Science degree (1989) in botany from Brigham Young University.

Craig L. Clyde is a Wildlife Biologist with the Central Region, Utah Division of Wildlife Resources, Springville, UT. He earned a Bachelor of Science degree (1985) in range resources (wildlife option) from Brigham Young University.

H. Duane Smith is Director of the Bean Life Sciences Museum and a Professor in the Department of Zoology at Brigham Young University, Provo, UT. He received Bachelor (1963) and Master of Science (1965) degrees in zoology from Brigham Young University and a Ph.D. degree (1969) in vertebrate ecology from the University of Illinois. He is a Certified Wildlife Biologist with The Wildlife Society.

Perry J. Hardin is an Associate Professor in the Department of Geography at Brigham Young University, Provo UT. He holds a Bachelor of Science degree (1982) in geography and a Master of Arts degree (1984) in climatology from Brigham Young University and a Ph.D. degree (1989) in geography from the University of Utah.

Research Summary

Cooperative research was conducted from May 1993 through October 1994 to better understand relationships between Rocky Mountain elk (*Cervus elaphus canadensis*) and domestic sheep inhabiting a 100.1 km^2 spring-fall rangeland in an aspen (*Populus tremuloides*)-dominated ecosystem in north-central Utah. Important findings include elk population estimates and structure, seasonal feeding site selection, preferences for forage, dietary overlap, animal unit equivalents between elk and domestic sheep, use of sheep salting placements by ungulates (elk, domestic sheep, and mule deer [*Odocoileus hemionus*]), natural mineral lick analyses, effects of biting flies on elk habitat use, habitat selection, and elk migration patterns. Three maps generated by a Geographic Information System (GIS) aid the reader in visualizing physical characteristics of the study area, vegetation cover types, and recommendations for management.

A total of 188 plant species were identified in the study area and poisonous properties listed. Of these, 142 were analyzed at feeding sites.

Mean dietary overlap was based on dietary similarity. The best estimate of mean dietary overlap was in summer, 1994 (36.4 ± 32.8 percent). A method to calculate animal unit equivalents (AUE's) incorporating dietary overlap resulted in an equivalent of 1:6.6 at this time. Thus it required 6.6 sheep to eat the same amount of forage as one elk in the study area on a suite of foods eaten in common by both elk and sheep in summer 1994.

In spring, elk selected feeding sites with high amounts of herbaceous biomass, east-west-facing aspects, and near roads. In summer and fall, elk feeding site selection was related to optimal vegetation and topography. Sheep, which grazed in the area in summer and fall, selected feeding sites based on variables related to management by herders such as the distances to a sheepherder and the nearest salt placement, and the amount of herbaceous biomass at feeding sites.

Nutritional analyses were performed on those species that composed at least 90 percent of elk and sheep seasonal diets. Crude protein was the most consistent and significant ($P < 0.05$) nutritional component influencing

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324 25th Street
Ogden, UT 84401

variation in elk forage preference. Natural mineral licks provided elk with essential minerals, including magnesium, sulphur, and calcium. Sheep did not regularly visit these licks, and salt placed for sheep lacked in magnesium. Therefore, sheep exhibited a preference for magnesium-rich forages.

Management recommendations intended to facilitate ecosystem-based management are found in sections on road closures, aspen regeneration, riparian habitat restoration, weed control and maintenance of native plant communities, sheep salt supplements, stock water developments, natural mineral licks, and elk hunting.

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Maps were printed separately from this publication and are in a pocket in the back of this book.

Map 1—Willow Creek Elk and Domestic Sheep Interactions Study Area, Heber Ranger District, Uinta National Forest: 1993.
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Introduction

Graves and Nelson's (1919) observations on the remnant North American elk herd persisting in the Yellowstone National Park area led them to conclude that when domestic sheep consumed most of the available forage on summer ranges, elk would be noticeably affected in their natural movements and would suffer heavy winter losses as they moved onto these ranges for the winter. Even light stocking of summer ranges by sheep would cause elk to move to areas far away from sheep due to the high amount of human activity associated with sheep grazing (that is, herders and dogs). Following the initial work of Graves and Nelson more technical research has focused on elk and domestic sheep interactions and possible competition between them for forage.

An Expanded History of Elk in the Strawberry Area

Elk (*Cervus*) originated in Eurasia during the Pliocene epoch (2 to 5 million years ago, Strickberger 1990) and arrived in North America via the Bering-Chukchi platform by the Pleistocene epoch (2 million to 5,000 years ago, Bryant and Maser 1982; Dawson 1967; Strickberger 1990). Bryant and Maser (1982) reported elk did not appear in the North American fossil record until the Illinoian glacial stage (at least 120,000 years ago). Fossil elk are common in the Alaskan refugium (that part of Alaska that remained free from glaciers), and all of these fossils are most likely from the Wisconsin glacial stage (70,000 to 10,000 years ago) (Bryant and Maser 1982).

Hopkins (1967) referred to Beringia as the once connected geographical area of western Alaska, Northeastern Siberia, and the shallow parts of the Bering and Chukchi Seas. Hopkins indicated that this area once bridged the Bering Straits. Geist and Francis (1991) reported that as ice melted and ocean levels rose 12,000 to 9,000 years ago, central Beringia was flooded, effectively separating elk into Siberian and North American populations. This assumption is supported by the fact that "the typical Siberian elk (maral) cannot be distinguished from the typical North American elk," indicating recent separation (Geist and Francis 1991:41). Unlike elk, mule deer are native to North America. They originated from a hybridization of North American white-tailed (*Odocoileus virginianus*) and black-tailed deer (*Odocoileus hemionus columbianus*) 7,000 to 14,000 years ago (Geist and Francis 1990).

At the onset of glacial recession, elk moved southward and eastward into the rest of North America and became extinct in Alaska probably due to vegetational changes (grassland displacement by forests and the development of permafrost) caused by receding glaciers (Bryant and Maser 1982). Seton (1927, in Bryant and Maser 1982) estimated there may have been 10 million elk in North America before European settlement. Bryant and Maser (1982) reported Rocky Mountain elk were originally distributed over most of Utah, with the exception of extreme southern and southwestern Utah.

The ancient cultures of the Anazasi (who resided in the Lower Colorado Plateau) and Fremont (who resided in the Great Salt Lake Desert, edge of the Bear River marshes, Uinta Basin, and edges and foothills of the Central Mountain System) in Utah depended on big game animals for food (Harper 1986). Harper reported that elk were important in food bone caches at only a few sites used by these ancient people. Harper ranked the relative importance of five big game mammals to these people based on numbers of bones recovered from archeological site excavations. These animals were elk, mule deer, bighorn sheep (*Ovis canadensis*), bison (*Bison bison*), and pronghorn antelope (*Antilocapra americana*). Elk ranked last in importance in the edges and foothills of the central mountains in Utah, and third in the Uinta Basin in relative importance of big game to the Fremont. Mule deer and pronghorn antelope ranked first and second above elk in relative importance to the Fremont in the Uinta Basin. Bighorn sheep were most important to Fremont residing in the Great Salt Lake Desert, and bison were ranked first in importance at Fremont sites in edges of Bear River marshes. Mule deer bones dominated Anasazi sites, with bighorn sheep bones being nearly as prominent.

Crosland (1993) reported elk remains in the faunal assemblage of an Archaic and Fremont Indian site excavated at "Aspen Shelter." Aspen Shelter is on the Old Woman Plateau in Sevier County, UT. Here, mule deer elements comprised more than 85 percent of animal remains, including two elk phalanges, one elk rib, and one elk zygomatic. Only 0.15 percent as many elk (n = 4) as mule deer specimens (n = 2,748) were recovered from this site. These results may indicate that elk either were not easy animals to kill with the weapons used or did not occur in great numbers where these people resided. Comparatively, Kurtén and Anderson (1980) cited several authors to indicate that elk were prized game animals in prehistoric times, but elk remains at Archaic human sites were infrequent and less abundant than bones of deer (*Odocoileus*).

Durrant (1952) shows elk in Utah extending throughout the Uinta Mountains in northeastern Utah and occurring in mountainous regions in the center of the State from Idaho to the north and south to near Arizona. Elk distributions in southern Utah, before non-Indian settlement, extended along the northern portion of present day Washington County and southern Iron County to Nevada, and, in northern Utah, elk also inhabited the Raft River Mountains (Durrant 1952). Allen (1874:65, in Durrant 1952) reported elk were common in mountains bordering the Salt Lake Valley. According to Barnes (1922:14), an early botanist, Marcus Jones, stated in 1888 that elk were so numerous at La Motte Peak in the Uinta Mountains that they "tramped down the grass in the subalpine basin." Jones also reported that in 1889 he "heard bull elk fighting near Hayden's Fork of the Bear River" (Barnes 1922:14). Murie (1951) reported Rocky Mountain elk once occupied the entire State of Utah with the largest concentrations in the Wasatch and Uinta Mountains.

The Strawberry area is between the Wasatch Front and the Uinta Mountains, where elk were reported to be abundant historically. Therefore, it follows that elk occurred historically in abundance in the Willow Creek area. Barnes (1922) and Seton (1909, in Barnes 1922) related that the distribution of elk in Utah in 1500 included most of present Wasatch County. Thus, elk were native to the Willow Creek area and may have existed at robust population levels with more options available for critical winter range.

Elk were nearly extirpated from Utah by the beginning of the 20th century. Barnes (1922:14, in Durrant 1952), reported that in 1912 only seven indigenous elk were known to exist within the Uinta Mountains in the Wasatch National Forest, and an additional six indigenous animals possibly remained in Cache County. Durrant reported that 181 animals were transplanted into the State from Jackson Hole, WY, and Yellowstone National Park from 1912 to 1916. Additional transplants occurred after this time, and the final transplant from the Park areas in Wyoming was of 200 elk in 1924. Thus, it can be demonstrated that elk in Utah today are descended from native as well as Yellowstone and Jackson Hole elk. Barnes estimated 145 elk on the Uinta National Forest at the time of his 1922 work on the mammals of Utah. Durrant (1952) cited results from the Utah State Fish and Game Department in 1948 that reported a herd of 600 elk on the Nebo Unit in the western portion of the Uinta National Forest. Current elk concentrations in the eastern regions of the Uinta National Forest appear to be more recent and probably reflect in State transplanting since 1924.

History of Domestic Sheep in the Strawberry Area

Domestic sheep grazing in Utah commenced with European settlement in the mid-1800's. Sheep grazing was initiated on the Wasatch Plateau, in Central Utah, in the 1870's (Johnson 1964). Jones and Jones (1972, in Bowns and Bagley 1986) reported that livestock have grazed Cedar Mountain in southwestern Utah since the late 1860's, with sheep predominating since the late 1890's. U.S. Forest Service (1972:60) reported that prior to 1891, the entire Strawberry River drainage was set aside as an Indian reservation. At that time, grazing rights for the area were leased to the Strawberry Valley Cattle Company, which had approximately 10,000 head of cattle on the watershed. U.S. Forest Service (1972:6) also reported that "during the 1890's, Indian lands were leased and subleased to groups who ran both cattle and sheep." It follows then that domestic sheep grazing began in the Willow Creek drainage during the 1890's. Sheep grazing in this area must have coincided with the extirpation of elk native to the region.

Herds of wethers were grazed in the 1890's because lambs were usually not marketed. Within about 7 years, extensive forage and watershed damage had occurred around Strawberry Valley because of this grazing pressure (U.S. Forest Service 1972). Due to excessive livestock grazing, elderberry (*Sambucus* spp.) and mountain snowberry (*Symphoricarpos oreophilus*) had almost disappeared from the range by the time the Forest Service was created in 1905.

Dietary Overlap and Implications of Forage Competition

Nelson (1982) reported competition for food and space between elk and domestic sheep occurs primarily on high elevation summer ranges, although their use may overlap on a few areas of winter range. MacCracken and Hansen (1981) found food habits of domestic sheep grazed during the late spring on critical big game winter ranges in south-central Colorado overlapped those of mule deer by 15 percent, elk 46 percent, and cattle 53 percent. Elk and cattle diets averaged 39 percent similar in this same study.

On a northeastern Oregon mountain summer range, Pickford and Reid (1943) found forbs composed nearly 81 percent of the elk diet and about 24 percent of the sheep diet, and grasses and sedges composed about 13 percent of the elk diet and 33 percent of the sheep diet. Shrubs composed about 6 percent of the elk diet and were insignificant in diets of sheep. Because of the strong similarity of elk and sheep diets in their study area, Pickford and Reid felt that common range use by elk and domestic sheep constituted dual use.

Olsen and Hansen (1977) found elk and sheep seasonal dietary overlaps were 18 percent for summer, 24 percent for fall, 53 percent for winter, and 26 percent for spring in the shrub-steppe and saltbush habitat of the Red Desert in southwestern Wyoming. Elk relied more on grasses and sheep more on shrubs in this area where forbs were minor constituents of the flora. Nelson (1982) cited this study and those of Nichols (1957b) and Stevens (1966) to conclude that on most elk summer range where grasses and sedges are the elk's primary food, forage competition with domestic sheep is limited.

Grazing Effects on Plant Succession

Grazing can alter plant community succession and therefore change potential development of ecosystems. These changes would be dictated by factors such as plant community composition and the resiliency of individual species to grazing. Gibson and Brown (1992) theorized that the influence of grazing on plant community succession in practice would be intermediate between two extreme hypotheses. One hypothesis describes grazing as maintaining vegetational communities in a mid-seral stage. In this case the cessation of grazing would allow the community to progress toward a climax state, and the initiation of grazing in a previously unaffected community would cause the plant community to regress to an earlier seral condition.

A second hypothesis suggested by Gibson and Brown (1992) holds that grazing may cause succession to "deflect" along a different sere to a plagioclimax. In this scenario, the termination of grazing would catalyze the successional trend as if grazing were never a factor, but the vegetational progression would be by another route. In this deflected succession scheme, seral stages of the ungrazed succession would not be recognizable.

Ellison (1954) reported that on the Wasatch Plateau in central Utah, excessive cattle herbivory caused ranges to be dominated by forbs, and that high sheep grazing pressure created ranges comprised largely of grasses. Johnson (1964) studied the effects of herbivory on plant succession on grazed and grazing-excluded areas used heavily by sheep prior to 1915 on the Wasatch Plateau in central Utah. By evaluating range studies conducted from 1915 to 1960 (a period of more restricted sheep grazing) on a grazed area there, he described the plant successional pattern as changing from annual forbs, through perennial forbs, to grasses in that order. Ellison (1954) reported that four dominant vegetation types on the Wasatch Plateau were derived from original climax cover under the influence of livestock grazing.

Bowns and Bagley (1986) related the influence that sheep grazing a mountain meadow on Cedar Mountain in southwestern Utah had on plant species richness compared to an adjacent area normally excluded from sheep herbivory. They found 33 species in the ungrazed area with a predominance of 29 (88 percent) forb species and only four (12 percent) grass species. By contrast, only 18 species were found in the sheep-grazed pasture, including 13 (72 percent) forbs and five (28 percent) grasses. Bowns and Bagley also found that above-ground biomass was 1.9 times greater in the sheep-excluded area than in the grazed pasture, and that the ungrazed pasture contained more desirable species in terms of numbers and biomass.

In Rocky Mountain National Park in Colorado, the age structure of aspens was inversely correlated with elk population fluctuations (Olmsted 1979:89). Here, aspen stands that had received greater than 50 percent use showed a discontinuous age distribution with less than 1 percent of the trees less than 50 years old. Stands receiving less than 50 percent use displayed a bimodal age distribution where the 20- to 30-year-old age-class establishment corresponded with a period of elk population reduction.

Interspecific Consequences of Herbivory

DeByle (1985) noted that when sheep consume forage in aspen zones, sympatric elk move to more desirable areas due to a lack of succulent forage and ground cover. Rhodes and Sharrow (1990) reported that although May through September sheep grazing in Oregon's Coast Range reduced total October phytomass by 40 percent, sheep grazing resulted in grass forage in October higher in dry matter digestibility and crude protein than did ungrazed areas. They concluded this resulted in providing higher quality food items for Roosevelt elk (*Cervus elaphus roosevelti*) and black-tailed deer in winter.

By contrast, Mantz (1993) reported that spring elk grazing in the Uinta Mountains in northeastern Utah significantly lowered mid-season crude protein levels of forage in sampled dry meadows used by cattle in summer and fall. Although the decrease in crude protein levels of nearly 2 percent (13.28 versus 15.17 percent) was statistically significant, these protein levels should satisfy crude protein requirements of lactating and growing elk (French and others 1955) and domestic ewes (National Research Council 1985). Mantz (1993) also reported that spring elk grazing reduced the mid-season standing crop by an overall average of 26 percent for six meadows sampled during two growing seasons. A combination of spring elk grazing and summer cattle grazing reduced the autumn standing crop by 74 percent on three sampled meadows in 1992. Elk were attributed with consuming 36 percent of this late-season amount.

Clegg (1994) reported elk densities at the Deseret Land and Livestock Ranch in northern Utah were significantly lower in pastures with sheep present. In this study, introductions of livestock into pastures resulted in deer and elk density declines of up to 92 percent. Some elk and deer did remain in sheep-grazed pastures in small areas where sheep bands had not grazed. Clegg found the bite rate of foraging elk increased significantly in areas previously grazed by cattle. This suggests that in response to the seasonal depletion of forage by livestock, elk ate more often to obtain an adequate intake.

Present Social Considerations in Utah in Regards to Elk and Livestock Management

Few topics stir emotions like a discussion of the growth of Utah's elk herd since the early 1980's, and the issues surrounding management of that herd. The polarization of attitudes concerns who will exercise control of management practices pertaining to elk on both public lands and private property. Utah sportsmen and women generally view the growth of the elk herd with unrestrained enthusiasm. This enthusiasm is communicated to the Utah Division of Wildlife Resources through support of increased license fees and purchases of additional big game range and from a finely organized, unified, Statewide sports organization. The Division must balance its management of elk within an environment of concern (for example, issues expressed by each elk user group, finite limitations of available habitat, depredations on private property, the Division's responsibility for other species such as mule deer, and many other issues). Furthermore, the Division must exercise its responsibility within budget constraints determined by the State legislature.

Livestock operators holding historical, legal, grazing permits for cattle and sheep on State and Federal rangelands have found increasing numbers of elk on those lands, potentially competing for a limited forage base within set allowable use parameters. During this period of elk population increases, livestock numbers have often been reduced on various Federal land grazing allotments. The objections of these livestock owners to these conditions are being communicated to local State and Federal agencies. They also exercise considerable influence through direct contact with State and Federal legislators.

The U.S. Forest Service is undoubtedly responsible for the bulk of habitat management for most of the State's elk herd. But the seasonally migratory herds of elk often occupy large portions of land administered by the Bureau of Land Management, and occupy private rangeland and farmland. A relatively new but astute group of people want to enjoy elk from a strictly esthetic standpoint. More polarized opinions express antihunting and antimanagement (because this calls for hunting) sentiments and also push for the cancellation of grazing permits for domestic livestock on Federal lands. All these various problems, positions, and viewpoints concerning elk are now focused on personnel responsible for the wise management of National Forest ecosystems.

Study Focus and Objectives

An intensive cooperative study was initiated in summer 1993 by the Uinta National Forest and Utah Division of Wildlife Resources in conjunction with Brigham Young University personnel to gain an understanding of elk and domestic sheep summer forage and habitat uses and possible interspecific interactions. Scientific measurements were taken in the Willow Creek drainage on the Heber Ranger District of the Uinta National Forest. Analyzed data are supported and set forth in such a way as to be readily available for application to management problems. The project proposal prescribed data collection sufficient to address the following questions:

1. What are the population density, classification, and distribution of elk during the time when they use the study area. What other important wildlife species are also found on the study area?
2. What are the distribution, band size, and movement patterns of sheep using the area in their traditional manner?
3. What is the species composition and seasonal variation in diets of sheep and wild, naturally adapted elk using the study area? How many kilograms per

hectare of herbaceous forage are available to elk and sheep in the various plant community types represented in the study area?

4. Can forage use and degree of use be attributed to single or dual use by these principal herbivores?
5. Can the functional importance of specific habitat components and habitat types be identified on a daily and seasonal basis for elk and sheep?
6. Can the impact of dietary use of vegetation and other impacts be reliably assigned to each principal herbivore. Can recovery rates of a significant number of sites be monitored with reliability on a seasonal or yearly basis?
7. Can specific fragile habitats, such as riparian zones, be assessed for condition and trend in diverse and complementary ways? Can the periodicity and longevity of use be attributed to each principal herbivore?

The overall objective was to investigate multidimensional interactions of elk and domestic sheep along with their separate and combined relationships with important components of this forest ecosystem. Specific objectives were:

1. To quantify the seasonal population density of elk and sheep within the study area as well as document their patterns of movement, habitat use, and reproduction (elk).
2. To determine seasonal diets of elk and domestic sheep in seasonal sympatry and allopatry within the study area.
3. To obtain estimates of key forage production, without use by ungulates, in each principal habitat type where multiple use occurs and/or in single use areas showing damage or decreasing condition.
4. To determine the functional importance of specific sites, habitats, and components on a daily and seasonal basis (for example, elk calving areas and sheep bedding grounds).
5. To identify habitats that may be (or have been) negatively impacted by the herbivores, either in consort or separately, and establish a baseline condition for fragile habitats.

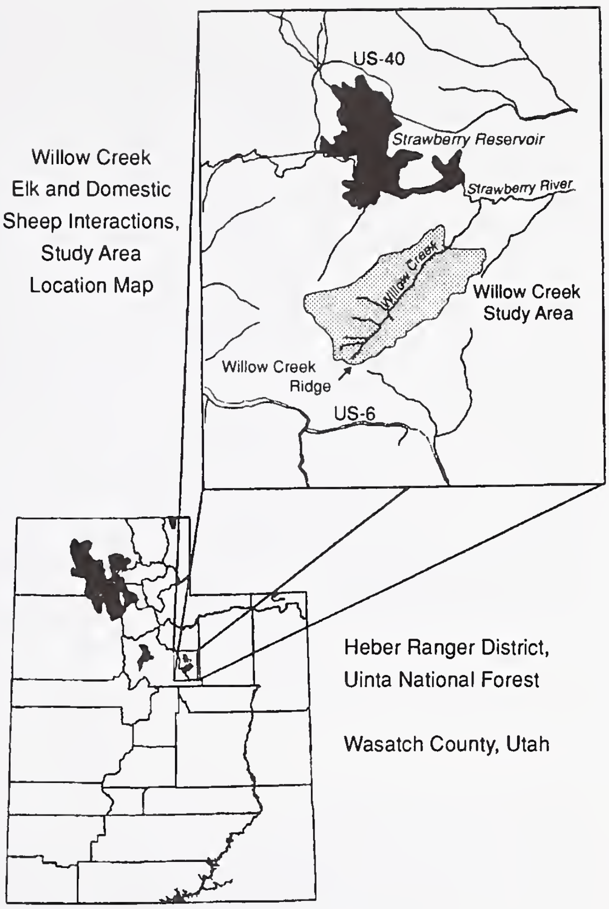


Figure 1—Location map of the Willow Creek elk and domestic sheep interactions study area.

Study Area

The Willow Creek drainage is southeast of Strawberry Valley in north-central Utah (fig. 1). Willow Creek flows into the Strawberry River about 2.25 km (1.40 mi) downstream (east) from the Soldier Creek Dam portion of Strawberry Reservoir. From its confluence, Willow Creek extends upstream in a southwestern direction for about 10 km (6.21 mi) to its point of origin near Willow Creek Ridge (fig. 1). The study area comprises 100.1 km^2 (24,735 acres) of U.S. Forest Service land administered by the Heber Ranger District, Uinta National Forest. Elevation ranges from 2,396 m (7,861 ft) along the northern extension of Willow Creek to 3,001 m (9,846 ft) on the northeastern ridgeline of Willow Creek Ridge. The Willow Creek Guard Station lying on Racetrack Creek at the headwaters of Willow Creek (maps 1 and 2) facilitated field work in the drainage. This guard station was built in 1931 to serve as an administrative site for Forest Service personnel in the Spanish Fork Ranger District because it was at the southern end of the summer sheep range of Strawberry Valley (U.S. Forest Service 1972).

A U.S. Natural Resources Conservation Service SNOTEL (SNOpack TELemetry) site is just south of Willow Creek Ridge at 2,607.8 m (8,550 ft) on the headwaters of the Right Fork of the White River and is designated as the White River 1 SNOTEL site. The 30-year (1961 to 1990) annual monthly precipitation average for the White River 1 SNOTEL site was 63.0 cm (24.8 inches) (Natural Resources Conservation Service 1994). Most of this moisture was precipitated as snow during late fall, winter, and early spring (U.S. Soil Conservation Service 1993). U.S. Forest Service

(1972) reported that annual precipitation at the Willow Creek Guard Station (2,501 m [8,200 ft]) was 50.8 cm (20 inches) and was fairly evenly disbursed between rain and snow. U.S. Forest Service (1972:53) reported that temperatures at the Willow Creek Guard Station ranged from –31.7 °C (–25 °F) to 29.4 °C (85 °F), and "killing frosts occur as late as June and as early as September in the normal season, but have occurred during all summer months."

Snow water equivalent according to the Soil Conservation Service (1993:31) is "the depth of water in the snowpack, if the snowpack were melted, expressed in inches." The first of April is a commonly used reference date to measure yearly snowpack (Ostler and others 1982). At the White River 1 SNOTEL on 1 April 1993, the snow water equivalent was 51.3 cm (20.2 inches) (U.S. Soil Conservation Service 1993), and on 1 April 1994, the snow water equivalent was 21.6 cm (8.5 inches) (Natural Resources Conservation Service 1994). Based on the snow water equivalence measurements from the standard reference date of 1 April, the 1993 snowpack held nearly 2.4 times the amount of moisture as the 1994 snowpack.

The ridgeline to the south of the creek is known as Willow Creek Ridge, while that to the north is commonly referred to as the Racetrack Ridge area. Numerous canyons are tributaries to Willow Creek. Major canyons on the west side of the drainage from north to south include French Hollow, Center Canyon, Buffalo Canyon, Racetrack Hollow, and Ice Spring Canyon (local name). Major canyons on the east side of the drainage from north to south are Cabin Springs Canyon (local name), Road Hollow, and Bear Trap Hollow (fig. 2).

The Willow Creek riparian zone is essentially roadless. An unimproved road down the ridge between Buffalo and Center Canyons allows relatively close access to Buffalo Canyon and Willow Creek. A closed

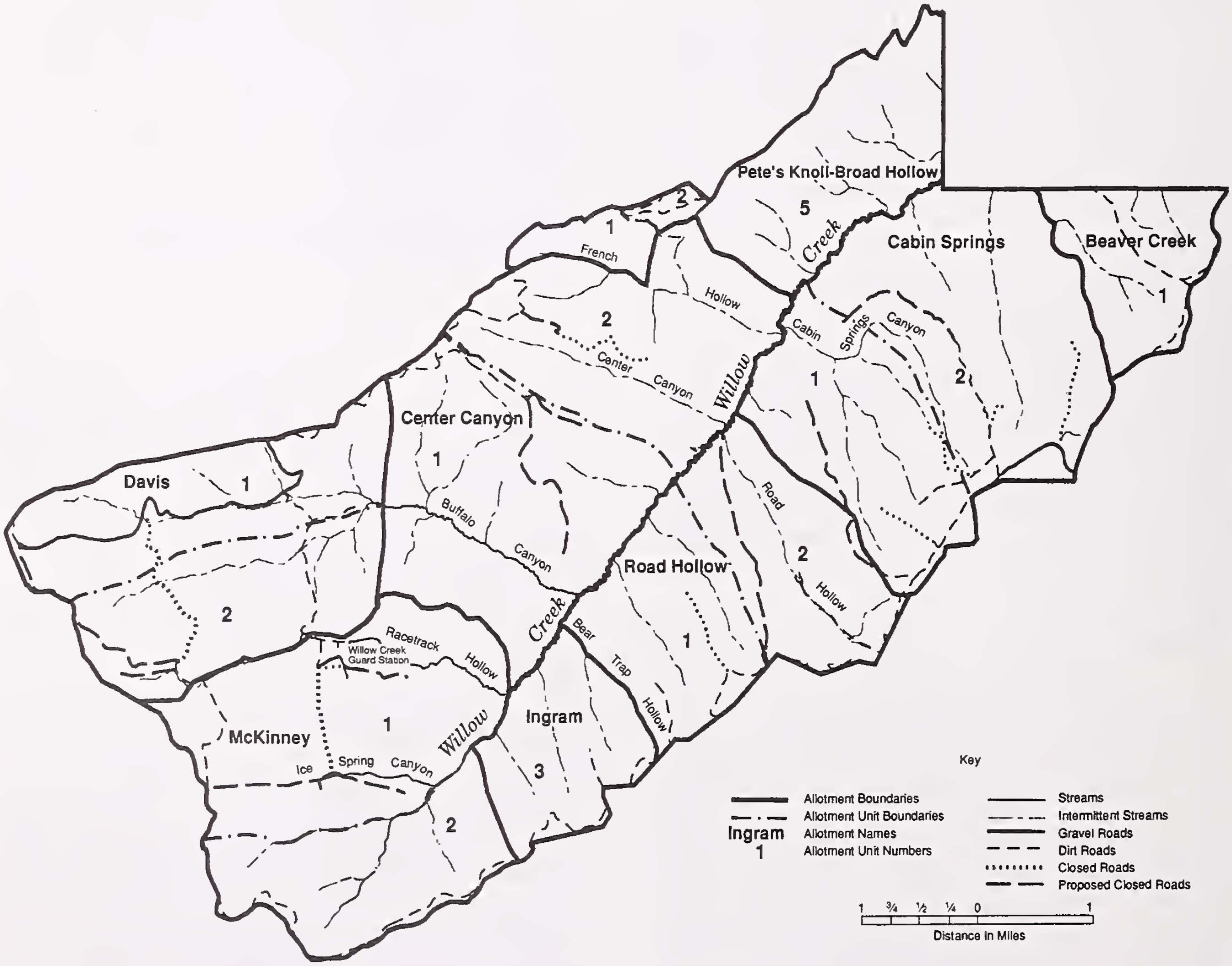


Figure 2—The Willow Creek study area in relation to important physical features.

road paralleling the south ridge of Road Hollow and descending into and following Willow Creek south to approximately Center Canyon is used by big game hunters to retrieve deer and elk with four-by-four or off-road vehicles. Good trails existing in French Hollow, Buffalo Canyon, Racetrack Hollow, Cabin Springs Canyon, and along Willow Creek offer entrance into the drainage for horse and foot traffic (fig. 2).

Most people access the Strawberry Valley and hence Willow Creek from a good system of roads connected to U.S. Highway 40 (fig. 1). A system of improved and unimproved roads allow people to directly access the southern portion of Strawberry Valley from several points along U.S. Highways 6 and 89 in Spanish Fork Canyon (fig. 1). A common route for entrance to Willow Creek from Spanish Fork Canyon is via the Sheep Creek Road. Less traveled roads leading to the Willow Creek Ridge road are found from the Right and Left Forks of the White River.

The whole drainage lying within National Forest boundaries serves as important late spring, summer, and fall range for domestic sheep. Five deferred-rotation grazing allotments (Cabin Springs, Center Canyon, Davis, McKinney, and Road Hollow) are administered by the Heber Ranger District (fig. 2 and maps 1-3). These allotments consist of two units containing 9.065 km^2 (3½ sections for a total of 18.13 km^2 or 7 sections) of land per allotment. The Beaver Creek, Broad Hollow/Pete's Knoll, and Ingram allotments are all grazed under a rest-rotation grazing system. The Beaver Creek and Ingram allotments contain three units, and the Broad Hollow/Pete's Knoll allotment contains five grazing units. These eight allotments subdivide the drainage. Parts of the Broad Hollow/ Pete's Knoll, Ingram, and Beaver Creek allotments lie outside the Willow Creek drainage. The Ingram allotment includes parcels within the Willow Creek drainage, private land, and acreage within the boundaries of the Spanish Fork Ranger District, Uinta National Forest; it is administered by the Spanish Fork Ranger District. The Beaver Creek allotment lies partially within the Ashley National Forest, although this allotment is administered by the Heber Ranger District.

An additional sheep allotment, administered by the Ashley National Forest, lies partially within the Willow Creek drainage and bounds the Beaver Creek allotment on the northeast of the study area. To the north, the study area is bounded by a cattle ranch.

Vegetational zones in the study area include riparian, sagebrush-grass, aspen-snowberry, and conifer. Large areas of big sagebrush (*Artemisia tridentata*) and silver sagebrush (*Artemisia cana*) have been previously burned and reseeded throughout the drainage. A complex of viscid rabbitbrush (*Chrysothamnus viscidiflorus*) and grasses including oniongrass (*Melica bulbosa*), Nelson needlegrass (*Stipa nelsonii*), Letterman needlegrass (*Stipa lettermanii*), smooth brome (*Bromus inermis*), mountain brome (*Bromus carinatus*), and slender wheatgrass (*Elymus trachycaulus*) now dominate these sites. Areas once dominated by sagebrush and burned and chained in the 1970's (S. Smith 1993, personal communication) on the northeast portion of the drainage, particularly in the Cabin Springs allotment, have been seeded with meadow fescue (*Festuca pratensis*). Additional, large upland flatter areas on the west side of the drainage have been seeded with smooth brome. A sagebrush-smooth brome complex currently dominates these sites. Riparian zones dominated by Willows (*Salix* spp.), sedges (*Carex* spp.), and other mesic species such as wiregrass (*Juncus arcticus*), and tufted hairgrass (*Deschampsia caespitosa*) occur along Willow Creek and tributaries as well as various seeps, springs, and beaver ponds in the drainage. Formerly designated (by the Intermountain Region, U.S. Forest Service) sensitive plant species in the drainage include: a grass, the sedge fescue (*Festuca dasyclada*); and a forb, the Dragon milkvetch (*Astragalus lutosus*).

Methods

References were initially written according to guidelines for The Journal of Wildlife Management (Ratti and Ratti 1988). However, many modifications were necessary to accommodate publishing requirements. Also, English units were provided at times with metric measurements to make data more applicable for some management considerations.

Ecological Sites

Ecological site data for elk classifications, sheep classifications, elk feeding sites, sheep feeding sites, salting locations, sites of importance (natural mineral licks, sheep bed grounds, elk dry-wallows, and stock watering facilities), and elk biting fly indices were essentially collected in the same manner. Methods used specifically to collect various data will be presented under subheadings. The following briefly explains techniques used to collect basic ecological site information:

1. A date was assigned using the Julian Calendar and the military time of data collection.
2. A Celsius thermometer was used to measure temperature; a wind force equivalent was estimated using the Beaufort Scale of Wind Force and Equivalents (Society of American Foresters 1955); and sky condition was gauged against a sky condition scale.
3. United States Geological Survey maps were consulted to determine which allotment the site was in, the cadastral map location, elevation, and to measure straight line distances of observers from animals,

roads, water, sheep salting licks or natural mineral sources, ridgetops, human activity, known sheep bed grounds, and occasionally habitat edge.

4. A Trimble, Basic Plus Global Positioning System (GPS) field unit, supplied by the Heber Ranger District, was used to gather Universal Transverse Mercator, northing and easting coordinates, and to assign waypoints for data collection points.

5. Compasses with clinometers were used to measure slope and aspect in degrees. Because aspect data are circular, aspect measurements used in statistical testing were sine and cosine transformed. Because sine and cosine are cofunctions of each other, it follows that the cofunctions of complementary angles are equal (Smith 1991). Sine transformations pertain to east-west aspects. Cosine transformations pertain to north-south aspects.

6. Sixteen habitat types defined from ground observations were used to classify habitat and habitat edge types. When observed, additional habitat and edge types were recorded.

7. Kind of habitat edge was selected from five standard types as follows:

1 = Riparian
2 = Sharp edge (less than or equal to 5 m)
3 = Ecotone edge (less than or equal to 6-20 m)
4 = Edge of three habitat types
5 = Edge of greater than or equal to 3 habitat types

Elk Herd Classifications and Habitat Use Analyses

1. Not all elk seen early in the field season (June through August) were classified due to time constraints. In September and October, elk sightings in the drainage became scarce, and in all but one instance (when time was limited), elk were classified.

2. After radio collar attachment in July 1993, the number of collared cows in each herd was recorded. These data were used in analyses as modified mark-recapture data (Otis and others 1978) to estimate elk populations in the area. All counts of elk were incorporated in a Lincoln Index (Lincoln 1930) to calculate an estimate of population density for the Willow Creek drainage:

$$\hat{N} = \frac{CM}{R}$$

where

$\hat{N}$ = estimated density of total population
C = size of the second sample
M = total marked in the population
R = number of marked individuals in the second sample.

The Lincoln Index requires sampling a closed population. For use of this method in the study area, it was assumed that emigration was balanced by immigration. Data were averaged by month as the premise for a closed population.

3. Using binoculars and spotting scopes, elk herds were counted and classified according to cows, calves, immature bulls, mature bulls, and unclassified elk (no classification certain, except species).

4. Using a random number table, one elk per herd was selected by counting either from right to left to single out an animal corresponding to the random number. Focal-animal sampling (Altmann 1974) of this elk was then performed to determine behavior. Behavior was assigned to one of 16 categories, and time spent at each activity was recorded.

5. If an elk was foraging on herbaceous or woody vegetation, and a feeding site was selected, then an exact location of feeding was ocularly determined. In most cases, a crude map was sketched on the back of the data form for later use as a guide to exact feeding site locations.

6. Data forms for recording horizontal obscurity cover were constructed according to details given by Skovlin (1982). A sight distance where 90 percent of the board was obscured was recorded in all four of the cardinal directions. Compasses, binoculars, and range finders were employed to obtain these data. The distance was either paced or ocularly estimated. In 1993, some elk locations not used for feeding site analyses were ocularly evaluated for cover by visualizing an elk at the location observed and estimating sight distances in the four cardinal directions. The distance to nearest horizontal obscurity cover was also judged and the habitat type at that location was recorded.

7. Great caution was used to not disturb elk at classification sites, especially those used for feeding site analysis.

8. Any other wildlife species seen near the elk were also recorded according to species, number, and distance from elk.

Elk Biting Fly Index

1. These data were taken at locations of elk classifications in 1994 where waypoints and Universal Transverse Mercator coordinates had already been assigned. This practice complemented GIS-generated maps. Work commenced from 3 June until 3 September 1994 when noticeable fly activity ceased due to frost.

2. One horse was selected (Altmann 1974; Brazda 1953) and either tied to a tree or shrub or held by the lead rope at the selected location.

3. Using a 10-minute stop watch (Collins and Urness 1982), the researcher would count and record all flies (Tabanidae) biting or attacking the left or rear portion

of the horse directly behind the saddle bags and around the genitals. The remaining side would then be counted in the same manner. Depending on circumstances (one or two observers and whether the horse was held by the lead rope or tied), both sides of the monitored horse would be counted at the same time. The left and right side totals were then summed to give a total index for each ecological site evaluated (Brazda 1953).

A multiple regression analysis was performed on the number of biting flies counted in relationship to environmental variables measured at elk biting fly index locations. Data were subject to best subsets of regression (Minitab 1993) to select those variables that contributed more to the overall regression model and less to total variation. To standardize this selection, the model with the highest adjusted R^2 and lowest C_p statistic was selected. According to Minitab (1993: 15-23), "when comparing models with different numbers of predictors, choosing the model with the highest adjusted R^2 is equivalent to choosing the model with the smallest mean square error." A small C_p indicates that the model is relatively precise (has small variance) and this precision will not improve much by adding more predictors (Minitab 1993:15-23). A plot of the residuals versus the fits determined that this regression met the assumptions of linear regression (Ott 1993).

Sheep Band Classification and Habitat Use Analyses

1. Because domestic sheep are relatively tame, and observers have closer viewing distances than with elk, bands were counted with and without the aid of binoculars and spotting scopes.
2. Numbers of black sheep and guard dogs seen mixed in herds were also counted. Herder presence and distance to sheep was also recorded.
3. Grazing and browsing sheep were selected and studied in much the same manner as elk (Altmann 1974), except that often sheep, which were more easily viewed, were selected for feeding sites to ensure that a feeding site would be reliable. Maps detailing sheep feeding sites were also traced on the back of sheep classification forms.
4. Distances to cover for sheep were estimated in 1993. The distance to nearest obscurity cover was also judged, and the habitat type at that location was recorded. In 1994, the distance of sheep to obscuring elk horizontal cover was obtained as described earlier for elk (Skovlin 1982).
5. Care was taken to not disturb sheep, especially at locations used for feeding site analyses.
6. Wildlife species seen near the sheep were also recorded according to species, number, and distance from sheep.

Feeding Sites

1. A rapidly deployed assembly of tied cords was created to establish 100 m^2 feeding site microplots. This assembly was centered upon the middle of the located feeding site.
2. All similar ecological site data and Global Positioning System information were transcribed from elk and sheep classification forms.
3. Upon inspection of the 100 m^2 plot, a woody canopy species, if any, which covered more of the plot than any other woody species was recorded. A mean height was measured and a percent canopy cover of this woody species was assigned after frequently consulting with a guide for estimating cover (Anderson 1986).
4. Percent cover of soil, rock, plant, and debris/litter were estimated in the 10 by 10 m microplot employing the same method as used for percent canopy cover (Anderson 1986).
5. A small sample of soil was manipulated using the "Feel Method" (Brady 1990) as a guideline to assess soil texture.
6. The number of fresh elk or sheep (or both) dung piles were counted per 10 by 10 m microplot. Due to irregular numbers of pellets per defecation, concentrations of pellets were determined to be dung piles after inspecting relative numbers, location, direction, and distance to other pellets. Freshness was determined by color and softness.
7. Whether the site was known to have been grazed or trampled previously by elk or sheep was indicated. These two factors were listed by species if a positive answer applied.
8. Plot size of microhabitat analyses was based on a modification of sizes suggested in the Relevé Method (Muller-Dombois and Ellenberg 1974; T. S. Smith 1991). Five nested 0.25 m^2 frequency frames were placed in the 10 by 10 m microplots in the following manner. The first frame was positioned over the center feeding site and was designated as quad 1. The second quad was placed on the right side at the end of the cord pointing north. Quads 3 through 5 were then placed in clockwise fashion in like manner as quad 2.
9. A list of all woody and herbaceous species in each 100 m^2 microplot was tabulated in two ways. First, all species rooted in the five 0.25 m^2 nested plots, and in 1993 woody species contributing cover to these plots were listed. In 1994, a list of woody species was obtained as explained later. And second, species seen in 10 by 10 m microplots and not found in the 0.25 m^2 nested plots (beginning with elk feeding site 9) were also listed. Woody plants with a basal stem less than or equal to 0.32 cm in diameter were considered to be forbs.
10. The percent cover and mean height for each species within the nested plots was recorded. In 1993,

cover was also recorded for all shrub species extending over but not rooted in the 0.25 m^2 plots. Mean height was measured with a 2 m steel tape, and percent cover was ocularly estimated using Anderson's (1986) cover guide as a reference.

11. Dominant phenological states of each species in each nested plot were determined. Prereproductive and with green leaves were assigned a value of 1; 2 = flower stage; 3 = seed and fruit set; 4 = post reproductive, most seed fallen but some green foliage available; and 5 = entirely senescent, no green parts available.

12. Percent of herbaceous biomass removed was estimated to be the quantity of biomass per species in each microplot removed from the original available amount by herbivores.

13. Each species was then clipped, weighed, and saved in paper bags for further analyses.

14. In 1993, shrub age and form classes detailed in the Cole browse survey (Cole 1959) were recorded to classify shrubs rooted in or extending over microplots, excepting seedlings.

15. The proportion of plants showing forage use in the 100 m^2 plots, and found in 0.25 m^2 nested plots, were recorded for each species present. This was the second way in which forage utilization was determined at each plot. Initially, these data were acquired during a sweep of the 10 by 10 m plot while counting the numbers of plants per species. Eventually a more exact method for acquiring these data was developed. All sheep feeding sites and all elk feeding sites (from 1993 feeding site 9 on) employed this new method to determine percent of the number of plants used per species. Counts of each species in 1 m wide strips along the cardinal lines yielded a total sampled area of 22.6 m^2.

16. All feeding sites were sampled no later than 1 week after first locating elk or sheep.

Woody Species Sampling in 1994 Feeding Sites

1. A list of all woody species found in each 100 m^2 microplot was initially recorded.

2. The dominant phenology of each woody species in the 100 m^2 microplot was recorded.

3. Percent cover (Anderson 1986) was recorded for each woody species occurring in 100 m^2 microplots based on the percent of each 100 m^2 microplot covered by that species.

4. The average height of woody species occurring in each 100 m^2 microplot was measured with a 2 m steel tape, and this value was recorded.

5. The number of individuals per woody species occurring in the 22.6 m^2 belt transects in each feeding site were counted and recorded as a density (number of individuals per 22.6 m^2).

6. The number of individual woody species (by species) browsed on by elk or sheep were recorded in the 22.6 m^2 belt transect at each feeding site.

7. An ocular estimate of the percent of each woody species occurring in 22.6 m^2 belt transects at each feeding site available to elk (0 to 1.83 m) and sheep (0 to 1.53 m) (Cole 1959) was obtained and recorded.

8. An ocular estimate of the percent of biomass of each woody species consumed by elk or sheep and occurring in the 22.6 m^2 belt transects at each feeding site was obtained and recorded.

9. The closest individual to the center grazing location (0.25 m^2 nested frame number 1) of each woody species in each 100 m^2 feeding site microplot was located and the phenology recorded.

10. The percent of each of these woody plant individuals available to elk (0 to 1.83 m) and sheep (0 to 1.53 m) (Cole 1959) was obtained and recorded.

11. The percent of biomass removed through elk or sheep herbivory on these selected woody plant individuals was estimated by the percent of the annual current growth and woody plant biomass older than 1 year removed through elk or sheep herbivory. These three estimates of the percent use of woody plant biomass were recorded.

12. An estimate was made of the percent of each woody plant to be clipped to be equal to the percent of each selected individual woody plant consumed by elk or sheep. This percent was recorded.

13. An estimate was made of the weight (g) of the percent biomass used by elk or sheep of the individual woody species occurring closest to the center of the feeding site location, and this weight (g) estimate was recorded.

14. An equivalent of the amount in grams estimated to be used by elk or sheep of each individual woody plant by species was clipped and weighed, and this weight was recorded. This weight represented the weight estimated to be eaten by elk or sheep.

Feeding Site Data Analyses

Herbaceous and woody (1994 only) plant samples were oven-dried at 60 to 70 °C (Flinders and Hansen 1972) for 24 hours and weighed. The dried weights of plant samples were used to compute standing biomass (herbaceous species only), percent dietary composition, biomass utilization estimates by species and feeding site, and the percent water content in plant samples. Similarity of sheep and elk diets and of the use of biomass within the drainage was calculated using Kulczynski's mathematical expression of similarity (Oosting 1956):

$$SI = \frac{2w}{a + b} \times 100$$

where

SI = similarity index,
w = the least amount of an item (plant species) shared by two categories (for example, percent seasonal relative dry weight in diets; or, percent use of dry seasonal standing biomass), and
$a + b$ = the sum of percent seasonal relative dry weight of the item in diets a and b; or the sum of percent use of dry seasonal standing biomass (Flinders and Hansen 1972).

This same index of similarity (Kulzynski's) has been used to compare diets of elk and domestic sheep in other studies (MacCracken and Hansen 1981; Olsen and Hansen 1977). For herbaceous species in 1993 and 1994, and woody species in 1994, similarity was determined by the percent of each species in the seasonal diets (dry weight basis) of elk and sheep. For herbaceous species in 1993 and 1994, similarities were also determined by the percent of dry standing biomass used at feeding sites by elk and sheep.

Sheep and elk herbaceous forage preference was calculated for each feeding site using Ivlev's (1961) electivity index:

$$E_i = \frac{r_i - n_i}{r_i + n_i}$$

where

E_i = Ivlev's electivity measure for species i,
r_i = percentage of species i in the diet, and
n_i = percentage of species i in the forage base.

Electivity varies from –1.00 to +1.00, with values between 0.00 and +1.00 indicating preference; values between 0.00 and –1.00 indicate avoidance (Krebs 1989).

Proportions of each plant type (forbs, grasses, sedges, and rushes; and browse in 1994) in the diets of elk or sheep were determined. Utilization of herbaceous vegetation was expressed as the average percent of standing biomass removed per species and as the percent of all individuals utilized.

Calculations of animal unit equivalents (see explanation under the subheading "Macro and Micro Factors..." in the Results and Discussion section) were performed two ways. The first method used metabolic liveweights (MBW [$W_{kg}^{0.75}$]) (Cordova and others 1978) of elk and domestic sheep. This standard method calculated forage consumption based on the relative metabolic liveweight of elk to domestic sheep:

$$AUE = \frac{Elk\ Weight_{kg}^{0.75}}{Sheep\ Weight_{kg}^{0.75}}$$

The second method used to calculate animal equivalents included the percent of dietary overlap in ungulate diets in relation to their metabolic liveweights (Flinders 1988):

$$AUE = \frac{\dfrac{Elk\ Weight_{kg}^{0.75}}{Sheep\ Weight_{kg}^{0.75}}}{Proportion\ of\ dietary\ overlap}$$

Mean weight of adult elk in the study area was calculated based on the herd structure of the largest classified herd (n = 163 mature elk classified on 23 June 1994 at 0900 hours), divided into estimated proportions of age classes, and multiplied by average winter weights of elk (by age classes) in Yellowstone National Park (Hornocker 1970). This product was then divided by 163. Hornocker tabulated average weights of hunter-dressed (eviscerated) elk weighed in Yellowstone during winter 1961 to 1962 by Greer and Howe (1964). Quimby and Johnson (1951) reported that 3 year old male and female elk that were hunter-dressed in Yellowstone National Park during December 1949 constituted 68 and 67 percent of live weights, respectively. Hornocker (1970) adjusted the weights of hunter-dressed elk according to these guidelines to obtain liveweights of elk by age class. The use of winter weights was justified because there is a paucity of data on summer elk weights and elk enter the area initially from winter range and stay into the fall before traveling to winter range. Mean sheep weights were calculated by weight estimates of ewes provided by ranchers in the area (E. Butterfield 1995 and H. Wilson 1995, ranchers, personal communication).

Multiple regression analyses were performed on micro and macrohabitat variables measured at elk and sheep feeding sites with the percent use of herbaceous biomass, and on nutritional fractions implicated with Ivlev's electivity index of forage preferences. Data were subject to best subsets of regression (Minitab 1993) to select those variables that contributed more to the overall regression model and less to total variation. To standardize this selection, models with the highest adjusted R^2 and lowest C_p statistic were chosen. When adjusted R^2 values were high in many models, an adjustment was made to select a model where the C_p statistic was low. A plot of the residuals versus the fits determined that these regressions met the assumptions of linear regression (Ott 1993).

Salting Locations

1. Salting locations were found throughout the drainage during various travels.
2. Because these were fixed, geographical locations, weather variables were not measured.
3. Type of habitat edge and distances to edge and roads were added to the salting location data set later on in the 1993 field season. The distance to a ridgetop was added in 1994.
4. Features of the exact salting area including whether salt was present, if digging or chewing was present, and whether tracks were at the site, and if so, which ungulate species was involved, were recorded as categorical data.

Elk Dry-Wallows, Mineral Licks, Water Facilities, Sheep Corrals, and Bed Grounds

1. Important sites in the area related to elk and sheep distributions were located through various travels. Site type was recorded, according to categories (water ponds, water troughs, mineral seeps and springs, sheep bed grounds, elk scrapes, elk dry-wallows, and other).
2. Because these were fixed, geographical locations, weather variables were not measured.
3. In 1993, a distance to elk obscurity cover was estimated and recorded to document the relative usefulness to elk of each site. In 1994, a distance to elk obscurity cover was obtained as described for elk feeding sites and locations at elk dry-wallows and natural mineral licks.

Results and Discussion

An Explanation of the Appendices

Four appendices to this report include 16 tables. These contain valuable detailed information on the Willow Creek study area and the use of its vegetation, habitats, and minerals by elk and domestic sheep. Appendix A, tables A1 through A7, consist of data summaries, basic statistics, and indices concerning: use of plant species within forage classes; elk spring use of forage and spring dietary composition; Kulcynski's similarity indices of use of standing biomass and dietary proportions; numbers of plant individuals used; and Ivlev's electivity indices of forage preference.

Appendix B, tables B1 through B3, consist of tables of data and summaries that include: the nutritional analyses of major forage species; the percent seasonal water content in plant species; and the poisonous properties of all identified plant species in the study area.

Appendix C, tables C1 through C3, report data summaries and basic statistics concerning: the seasonal use of forage in plant communities; seasonal standing biomass by plant community type; and the density and seasonal use of woody species (shrubs and trees) by plant community type.

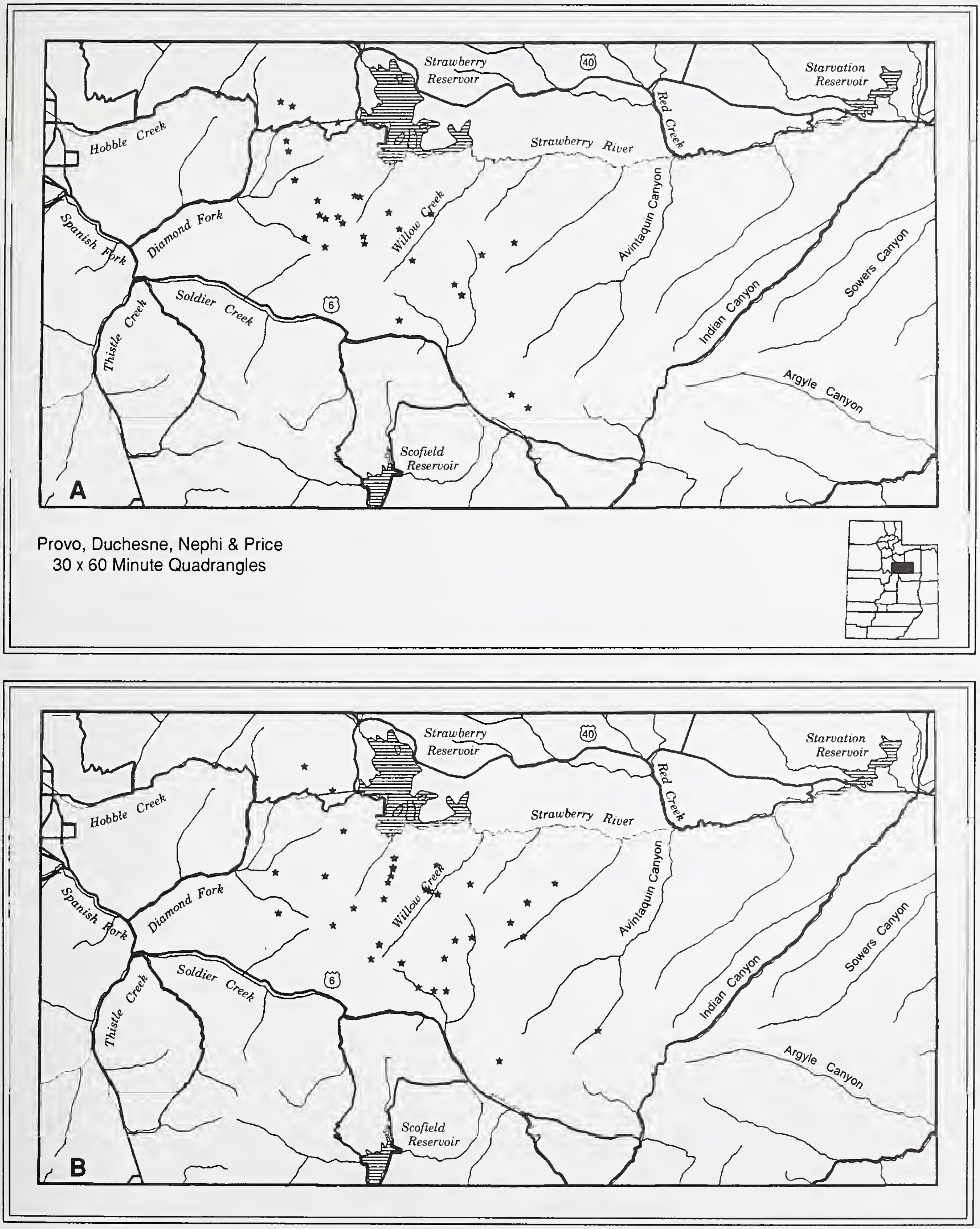
Appendix D, tables D1 through D3, report basic statistics and data summaries on macrohabitat use, salting locations, and other resource points such as natural mineral licks and elk dry-wallows.

Elk Movement Patterns, Radio Collar Placement, Aerial and Ground Monitoring

The first entrance into the area in 1993 was on 19 May. Elk tracks were observed crossing the drainage at the top of French Hollow and Center Canyon and on the ridge between Center and Buffalo Canyons (common name Butterfield Ridge) (fig. 2). Elk tracks were also observed near the study area. These tracks were east of Big Springs and approaching Broad Hollow. A fixed-wing airplane flight by the Utah Division of Wildlife Resources on 20 May 1993 revealed seven elk were in Road Hollow in a sagebrush-mixed brush habitat type and one elk was in Buffalo Canyon in an aspen-snowberry habitat.

In 1994, elk were initially found in the Willow Creek study area during an aerial survey conducted by the Utah Division of Wildlife Resources on 19 April. A collared cow with another elk (presumably her calf from 1993) were located in Center Canyon, and another collared cow with 44 other elk were near Willow Creek in the north end of the study area. On 5 May the first day of field work in 1994, in Willow Creek, evidence (tracks, pellets, and recently grazed vegetation) of elk use was observed in Buffalo Canyon.

Elk remained in the study area during the entire 1993 (19 May through 15 October) and 1994 (5 May through 14 October) field seasons. In 1993, elk use and occurrence in the area seemed to peak around the fourth week of August. On 26 August 1993, a nursery herd of 265 elk was classified in unit 1 of the McKinney allotment and on 27 August 1993, 106 elk were classified in unit 1 of the Center Canyon allotment. Elk distributions changed during the third week of August 1993. Factors associated with this occurrence were: (1) On 20 August, sheep moved to unit 2 on the Cabin Springs, Davis, McKinney, and Road Hollow allotments; and (2) the archery deer hunt started on 21 August. By 24 September 1993, elk began moving to winter ranges (fig. 3A). An elk exodus also seemed to occur in relation to the elk rifle hunt. Aerial flights monitoring elk that were radio-collared in the Willow Creek study area confirmed ground observations of this movement (maps 1 through 3). The last elk seen from land, in 1993, was a herd of 15 to 16 cows and



Provo, Duchesne, Nephi & Price
30 x 60 Minute Quadrangles

Figure 3—Locations on 24 September 1993 (A) and 28 September 1994 (B) of cow elk collared in Willow Creek and on Strawberry Ridge. Elk at these locations were considered to be inhabiting fall range.

calves on 12 October in unit 2 of the Cabin Springs allotment.

The largest herd of elk seen in 1994 was a nursery herd of 230 elk in unit 1 of the McKinney allotment on 23 June. This herd was near the location of the herd of 265 elk observed on 26 August 1993. Large herds of elk were common in July and August. The last large elk herd seen in 1994 contained 111 elk near Ice Springs in unit 1 of the McKinney allotment on 30 August. Elk numbers in the study area dwindled after the end of August, and the largest herd seen after that contained 21 elk in French Hollow in unit 2 of the Center Canyon allotment on 12 September. By 28 September 1994, Willow Creek elk began migrating to winter ranges (fig. 3B). The last elk seen from land, in 1994, were a cow and calf on 5 October in unit 1 of the Center Canyon allotment.

On 22 and 23 July 1993, contractors known as Wildlife Helicopter Management of Salt Lake City, UT, captured 10 cow elk in Strawberry Valley and 30 in the Willow Creek drainage (within the study area) (maps 1 through 3). C. Clyde, a Utah Division of Wildlife Resources Wildlife Biologist, assisted the pilot and gunner in applying right and left ear tags and a Lo-Tech radio transmitting collar and in taking a blood sample from each captured elk. Blood testing revealed all cows tested negative for brucellosis and blue tongue (C. Clyde 1993, personal communication). Radio collars from cow elk killed in 1993 were placed on six additional cow elk on 11 July 1994, in the east and southeast portions of the Willow Creek drainage. These collars were also placed by the previously mentioned contractor, and this brought the number of cows collared in the Willow Creek study area back to 30.

Fixed-wing aircraft flights to locate these instrumented elk were initiated by Utah Division of Wildlife Resources personnel beginning on 13 August 1993. Flights were carried out on the following eight dates in 1993: 13 August, 24 August, 10 September, 24 September, 22 October, 8 November, 24 November, and 10 December. Flights were carried out on the following 14 dates in 1994: 28 January, 23 February, 19 April, 6 May, 20 May, 3 June, 17 June, 18 July, 12 August, 8 September, 28 September, 20 October, 10 November, and 9 December. Including the capture, all 22 flights were used to collect location data from the air that were not readily available from the ground. Elk locations totaled 302 in 1993 and 477 in 1994. Pilot and biologist C. Clyde flew transect lines and located radio collar frequencies. Data gathered from each flight consisted of:

1. Elk locations in latitude and longitude (taken from a Loran unit and assigned a waypoint) (maps 1 through 3).
2. Elk herd size, if conditions allowed for counting (that is, out of trees).
3. Sheep locations in latitude and longitude (taken from a Loran unit and assigned a waypoint). Some cattle locations were also recorded because some elk either were collared in cattle grazing allotments or migrated to these allotments.
4. Plant community types present at elk locations were assigned.
5. Recounts where other collared elk were in the same herd.
6. Locations of elk whose radio signal indicated a mortality had occurred.

When more than one collared cow occurred in a herd, only one Loran location was taken from the air. In 1993, all collared cow elk had migrated from the study area by 24 November, and in 1994, all collared cow elk had migrated from Willow Creek by 10 November. Loran locations taken on the collared elk in and adjacent to the study area through 24 November 1993, and 10 November 1994 were plotted by month (map 1 for 1993; map 2 for 1994). All 1993 and 1994 aerial elk locations were overlain on the Gap vegetation layer on map 3. For comparison, all 1993 and 1994 elk and sheep locations taken on land were also plotted on map 3, and these gave an indication of elk and sheep seasonal movements within Willow Creek vegetation types.

Mortality signals received and located in the aerial surveys were then ground-searched by C. Clyde to find the dead elk. The cause of death was determined, if possible, and the collar was retrieved. As of 11 December 1993, there were six known mortalities, and one elk was presumed dead. As of 9 December 1994, there were four known mortalities. Table 1 data indicate that all of the 11 mortalities were attributed to hunting and none to natural causes. Two of the 40 (5.0 percent) elk cows collared in 1993 were observed to have previously suffered hunting inflicted wounds in their lower legs (C. Clyde 1993, personal communication). In 1993, a regular season antlerless elk hunt in Willow Creek and Strawberry Valley resulted in five fewer Willow Creek collared elk migrating to winter ranges than in 1994 (fig. 4). One cow elk collared on Strawberry Ridge was killed each year (fig. 5), and the one killed in 1993 was harvested on Strawberry Ridge (table 1). All harvested collared elk cows in 1994 were killed on winter ranges (table 1). The highest percent of winter mortality in 1994 was observed for Willow Creek collared elk that migrated to Emma Park winter ranges. Here, two of the five (40.0 percent) collared elk that had traveled to Emma Park winter ranges from Willow Creek were killed (fig. 4). In 1993, by comparison, one (25.0 percent) of four cows migrating to Emma Park from Willow Creek was killed (fig. 4).

On the average, the greatest distances that Willow Creek elk migrated to winter range were 43.1 km (SD = 31.5) to Avintaquin Canyon in 1994. This distance was 2.3 km less in 1993 (mean = 40.8 km, SD = 20.7) than in 1994 (table 2). Elk number 54 migrated

Table 1—Mortality of Willow Creek and Strawberry Ridge collared cow elk, 1993 and 1994.

1993 mortality[a]			1994 mortality[a]		
Collar No.	**Cause**	**Location**	**Collar No.**	**Cause**	**Location**
14[b]	Legal kill	Strawberry	16	Wounding	Sp Fk Cyn[d]
20[b]	Legal kill	Willow	52	Legal kill	Emma Park
24[c]	Unknown	Willow	56	Legal kill	Emma Park
26[b]	Wounding	Willow	74	Wounding	Avintaquin
34[b]	Legal kill	Willow			
66[b]	Wounding	Willow			
74[b]	Legal kill	Emma Park			

[a] No collared elk died in 1993 and 1994 from natural causes.

[b] These collars were placed on additional cow elk in Willow Creek in 1994.

[c] This cow elk collared in Willow Creek has never been retrieved, but is assumed to be an illegal kill, as the collar was never returned and all transmissions ceased following the 1993 regular hunt.

[d] Spanish Fork Canyon.

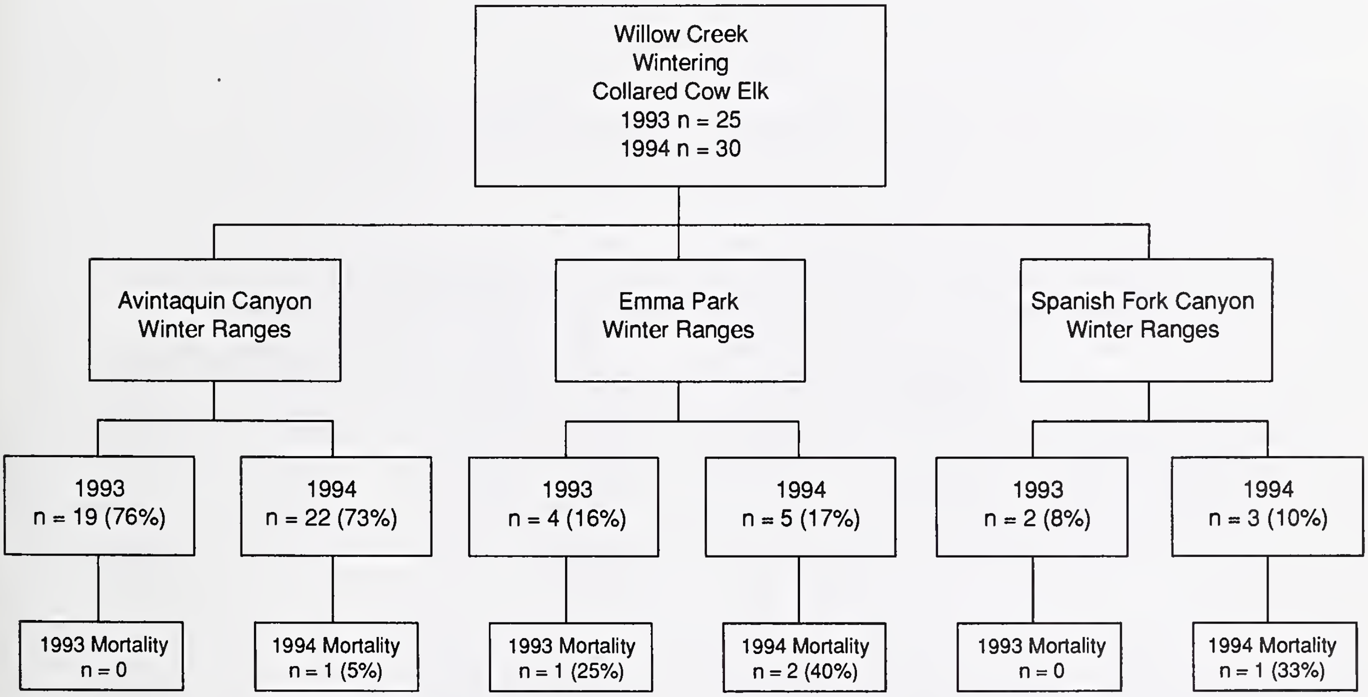

Willow Creek Wintering Collared Cow Elk 1993 n = 25 1994 n = 30
Avintaquin Canyon Winter Ranges
Emma Park Winter Ranges
Spanish Fork Canyon Winter Ranges
1993 n = 19 (76%)
1994 n = 22 (73%)
1993 n = 4 (16%)
1994 n = 5 (17%)
1993 n = 2 (8%)
1994 n = 3 (10%)
1993 Mortality n = 0
1994 Mortality n = 1 (5%)
1993 Mortality n = 1 (25%)
1994 Mortality n = 2 (40%)
1993 Mortality n = 0
1994 Mortality n = 1 (33%)

Figure 4—Winter range and winter mortalities in 1993 and 1994, of cow elk collared in the Willow Creek study area.

farther than any other collared elk during the 1993 to 1994 winter (C. Clyde 1993, personal communication). A flight on 23 February 1994 revealed this elk had traveled 110.5 km (68.7 miles) from where she was originally collared in Willow Creek to winter southeast of Starvation Reservoir. By 17 February 1995, elk numbers 48, 50, and 58 had migrated farther from their location in the study area on 18 July 1994 than any other elk. Elk numbers 50 and 58 were in the same herd and traveled approximately 109.9 km (68.3 miles) southeast to winter near the Green River. Elk 48 migrated a farther distance to winter range (1994-1995 winter) than any other elk during the study. This elk cow traveled east 124.7 km (77.5 miles) on a route through winter ranges in the Avintaquin Canyon area to winter near the Green River. On 17 February 1995, elk number 48 was nearly 16.1 km (10.0 miles) north of elk numbers 50 and 58 (C. Clyde 1995, personal communication).

Collared elk cow number 38 ranged closer to Willow Creek in 1994. She was in the Chipman Creek area (adjacent to Willow Creek) on 18 July 1994 and

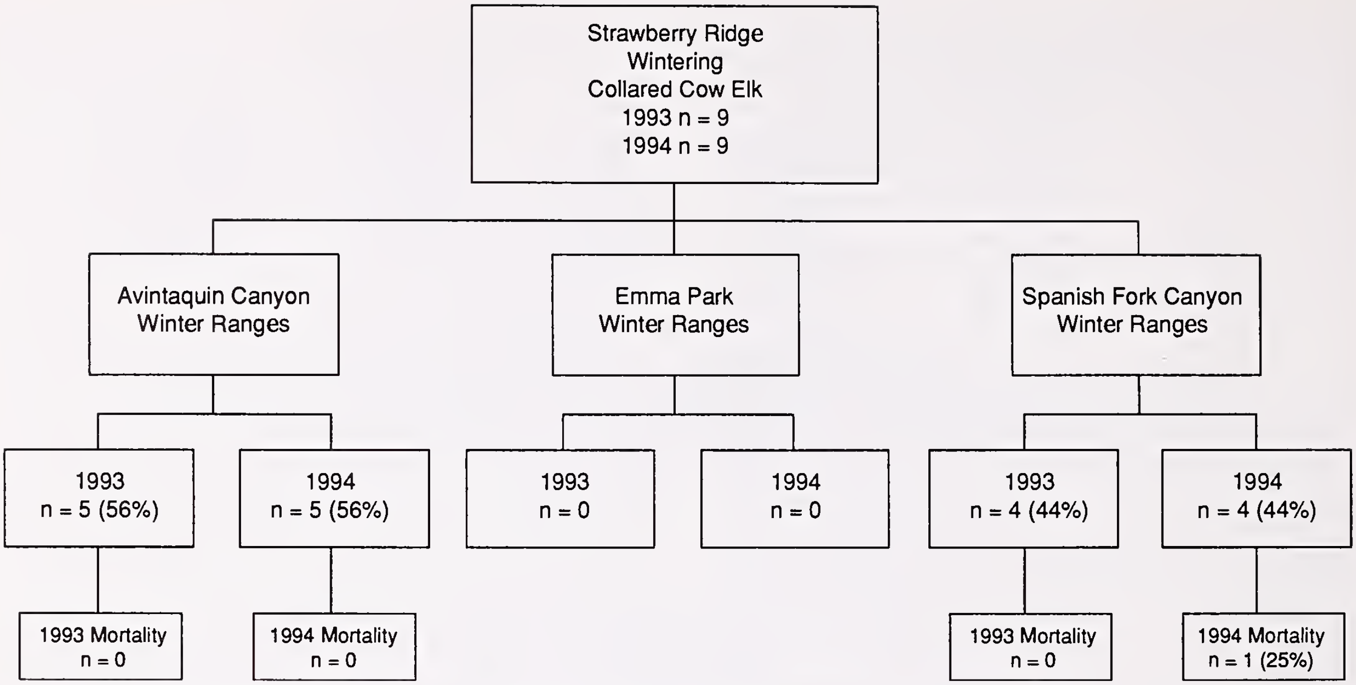


Figure 5—Winter range and winter mortalities in 1993 and 1994, of cow elk collared on Strawberry Ridge.

Table 2—Migration distances (km) of Willow Creek and Strawberry Ridge collared cow elk to winter ranges in 1993 and 1994.

	Avintaquin Canyon		Emma Park		Spanish Fork Canyon	
	Mean	SD	Mean	SD	Mean	SD
1993 Willow Creek	40.8	20.7	34.7	10.7	23.3	2.0
1994 Willow Creek	43.1	31.5	40.6	6.1	20.2	4.0
1993 Strawberry Ridge	40.2	10.4			24.1	5.7
1994 Strawberry Ridge	23.1	18.0			30.9	10.4

traveled 40.1 km (24.9 miles) to winter range in 1994. The distance traversed by cow elk numbers 48, 50, and 58 was closer to winter ranges during the winter of 1993-1994 than in the winter of 1994-1995. Elk number 48 traveled 50.4 km (31.3 miles) to winter on Avintaquin Canyon winter ranges during the winter of 1993-1994. Elk numbers 50 and 58 migrated between 24.6 km (15.3 miles) and 34.8 km (21.6 miles) to winter on ranges in the vicinity of Emma Park during the 1993-1994 winter (C. Clyde 1995, personal communication). It is believed that these collared elk cows (48, 50, and 58) migrated the additional distance to near the Green River in 1994 to escape hunting pressure caused by antlerless elk hunts on wintering elk in the Avintaquin Canyon and Emma Park areas (table 3). These data give an indication of the diversity of options available to elk that winter south and east of the study area.

The least distances Willow Creek elk migrated to winter ranges were to Spanish Fork Canyon in 1994 (mean = 20.2 km, SD = 4.0) and in 1993 (mean = 23.3 km, SD = 2.0) (table 2). No cow elk collared on Strawberry Ridge wintered on Emma Park winter ranges. Willow Creek collared cow elk migrating to Emma Park winter ranges traveled an average distance in 1993 of 34.7 km (SD = 10.7), and in 1994 of 40.6 km (SD = 6.1) (table 2). Cow elk collared on Strawberry Ridge migrated to Avintaquin Canyon winter ranges in 1993 an average of 40.2 km (SD = 10.4), and in 1994 an average of 23.1 km (SD = 18.0) (table 2). Compared to Willow Creek collared elk, Strawberry Ridge collared elk traveled farther to winter ranges in Spanish Fork Canyon. On the average, they traveled 0.8 km (mean = 24.1 km, SD = 5.7) farther in 1993, and in 1994 they migrated 10.7 km (mean = 30.9 km, SD = 10.4) farther to ranges in Spanish Fork Canyon (table 2).

Table 3—Anterless elk hunting permits per winter range destination of elk cows collared in the Willow Creek study area and on Strawberry Ridge, 1993 and 1994.

Anterless permits	Avintaquin Canyon	Emma Park	Spanish Fork Canyon
Regular season 1993	50[a]	0	385
Post season 1993	75	110	110
Total	125	110	495
Regular season 1994	0	0	0
Post season 1994	295	220	250
Total	295	220	250

[a] This hunt occurred before any collared elk had migrated to winter ranges in the Avintaquin Canyon area.

Figure 6A displays 1993 collared cow elk wintering areas (as of 28 January 1994) in 1993 to 1994, and figure 6B depicts the 1994 to 1995 wintering areas (as of 20 January 1995) of 1994 collared cows. Sample sizes and percents by winter range area for elk that migrated from Willow Creek (fig. 4) and Strawberry Valley (fig. 5) to winter ranges in 1993 and 1994 indicate that most (70.0 percent in 1993; 82.1 percent in 1994) of the collared elk migrated to eastern winter ranges. In 1993, six (15.0 percent) of the cow elk collared on Willow Creek and Strawberry Valley summer ranges migrated to Spanish Fork Canyon winter ranges to the west, and in 1994, seven (17.9 percent) of the 39 collared cows migrated to Spanish Fork Canyon winter ranges (figs. 4 and 5). In both 1993 and 1994, of the cows collared on Strawberry Valley summer ranges 56.0 percent migrated to winter ranges in the Avintaquin Canyon area (fig. 5). The remaining four cows (44.0 percent) traveled to Spanish Fork Canyon winter ranges in 1993 and 1994. In 1993, of the Willow Creek collared cows, 23 (92.0 percent) migrated to winter ranges to the east (Avintaquin Canyon = 19 [76.0 percent]; Emma Park = four [16.0 percent]). In 1994, of the cows originally collared on Willow Creek summer ranges, 27 (90.0 percent) migrated to eastern winter ranges (Avintaquin Canyon = 22 [73.0 percent]; Emma Park = five [17.0 percent]) (fig. 3). In 1993, two (8.0 percent) cows collared in Willow Creek wintered on Spanish Fork Canyon ranges. In 1994, three (10.0 percent) cows collared in Willow Creek migrated to Spanish Fork Canyon winter ranges (fig. 4).

Data from the Utah Division of Wildlife Resources indicate that the ranges used by elk in the fall are also used as early spring ranges as elk migrate back to Willow Creek and Strawberry Valley summer ranges. Willow Creek and Strawberry Ridge collared elk movements were contained on the south by Highway US-6 in Spanish Fork Canyon and generally by Highway US-40 to the north. To the west, Hobble Creek Canyon east of Springville, UT, was the western boundary, and most elk activity extended east only to Indian Canyon (fig. 7). A fair number of elk did move farther to the east to Argyle and Minnie Maud Canyons and south toward the vicinity of Price, UT. This entire region of elk activity overlays the Provo, Duchesne, Nephi, and Price 30 by 60 minute U.S. Geological Survey quadrangles located in north-central Utah (fig. 7).

Loran aerial flight locations of elk also indicated calving activities in the Willow Creek study area. According to concentrations of elk during the early June calving period, elk calving was centered in Buffalo, Racetrack, and Ice Spring Canyons (fig. 8; maps 1 and 2). The Chipman Creek area west of Trail Hollow and east of Indian Creek also attracted many elk during the early June calving period (fig. 8; maps 1 and 2). Elk number 76 was originally collared in Willow Creek in 1993. This cow migrated east of Willow Creek to the Emma Park area to winter. On 3 June 1994, this elk was in the Emma-Whitmore Parks area of Carbon County, UT (fig. 8). The Utah Division of Wildlife Resources flight on 17 June 1994 found that elk number 76 had migrated to near the south end of Willow Creek. It was assumed that this cow returned to calve. During summer, collared cow elk generally remained in proximity to early June calving areas as indicated by their locations on 24 August 1993 (fig. 9A) and 12 August 1994 (fig. 9B). A general pattern was observed for some collared cows to move in a northwestern direction from Willow Creek and Strawberry Ridge. Some of the elk cows collared on Strawberry Ridge crossed US-40 to the northwest of Strawberry Reservoir (fig. 9A,B).

Ground searching for elk with collars was done on a more limited basis. Elk locations first assessed from air at times were then tracked from the ground using a Telonics receiver. This method aided in locating more than 100 elk during the last week in September 1993 because the general location of elk radio frequencies at that time was known. This assisted in finding elk feeding site 22, and in 1994, elk feeding site 33 was found by this method.

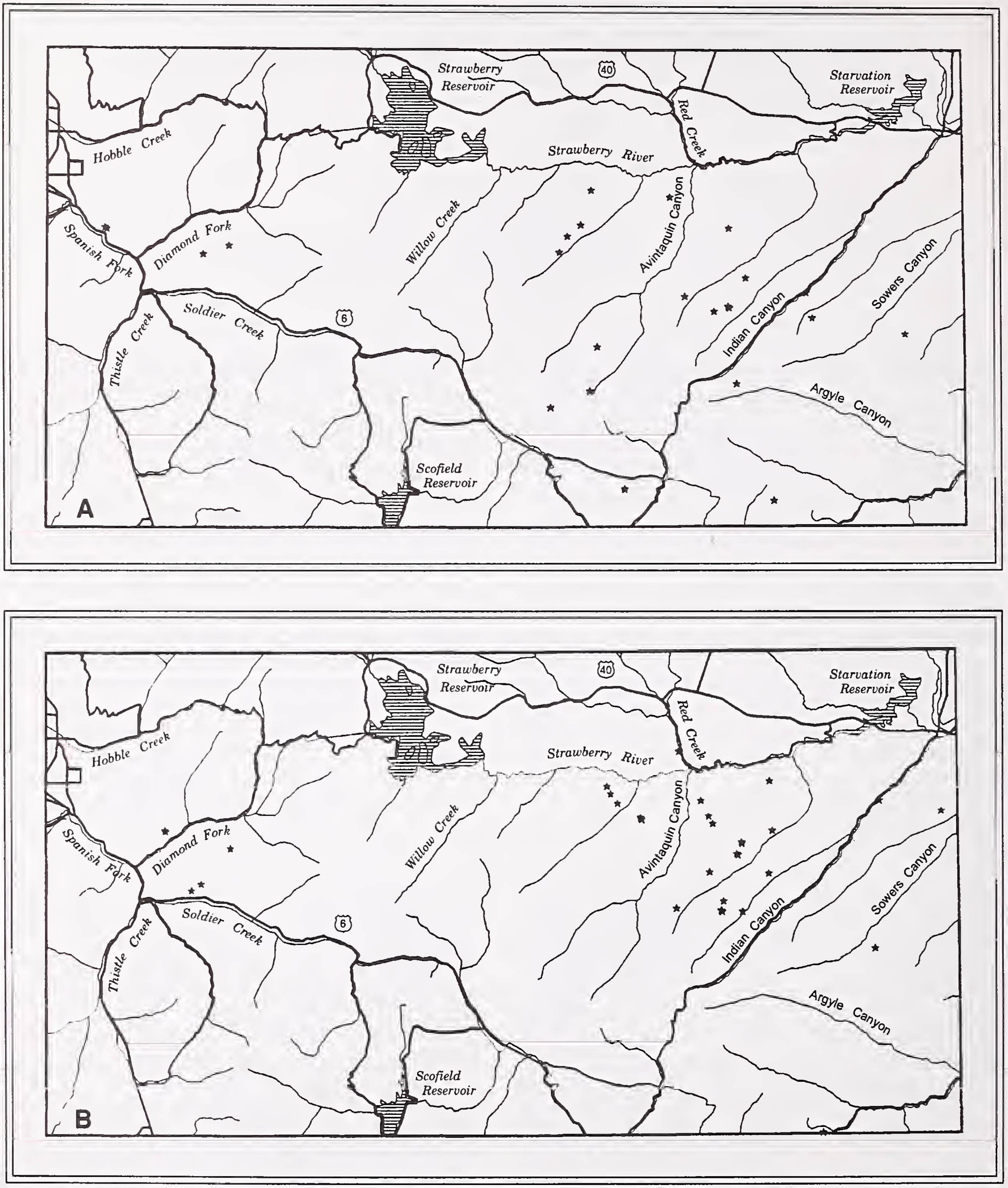


Figure 6—Locations on 28 January 1994 (A) and 20 January 1995 (B) of cow elk collared in Willow Creek and on Strawberry Ridge. Elk at these locations were considered to be inhabiting winter range.

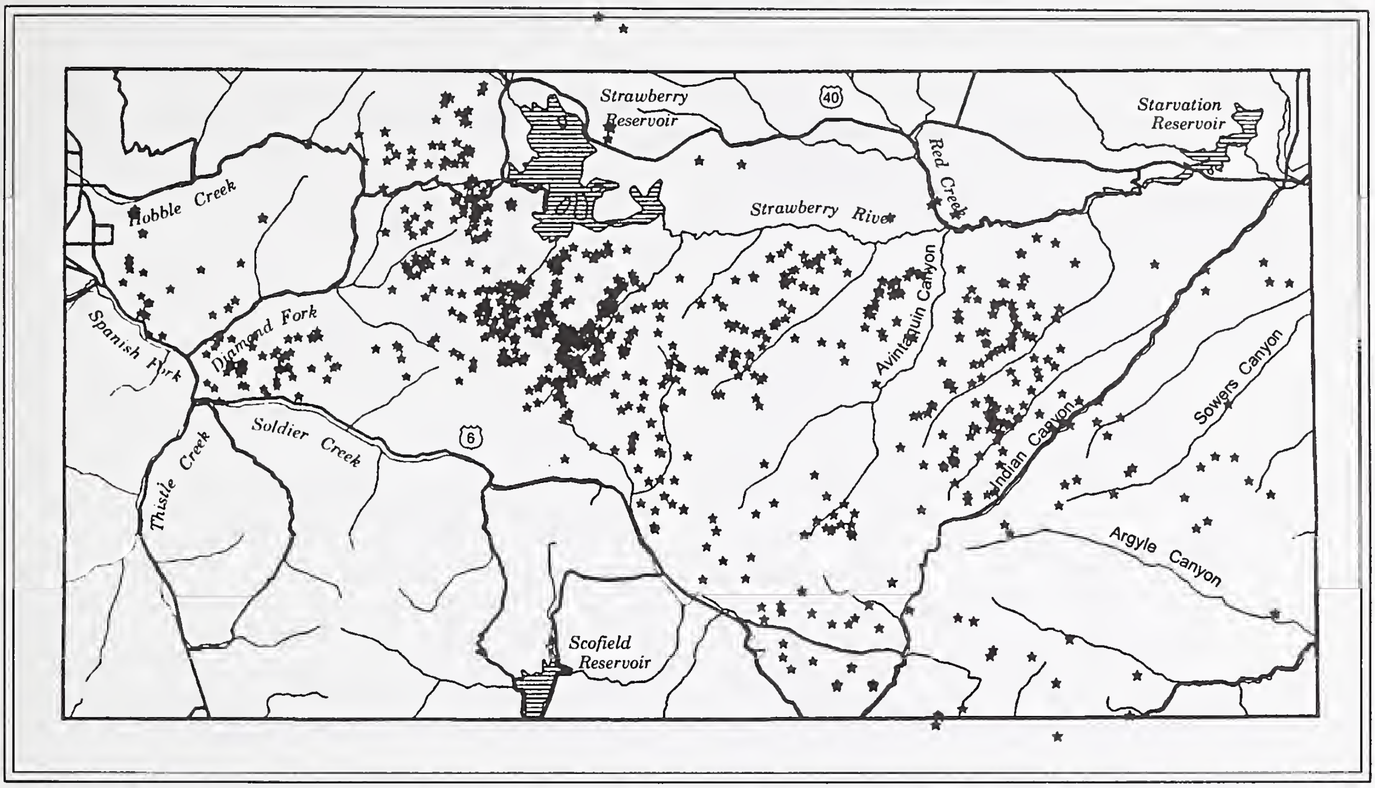


Figure 7—A display of all collared elk cows relocated by aerial surveys cumulative to 18 May 1995 (22 July 1993-18 May 1995).

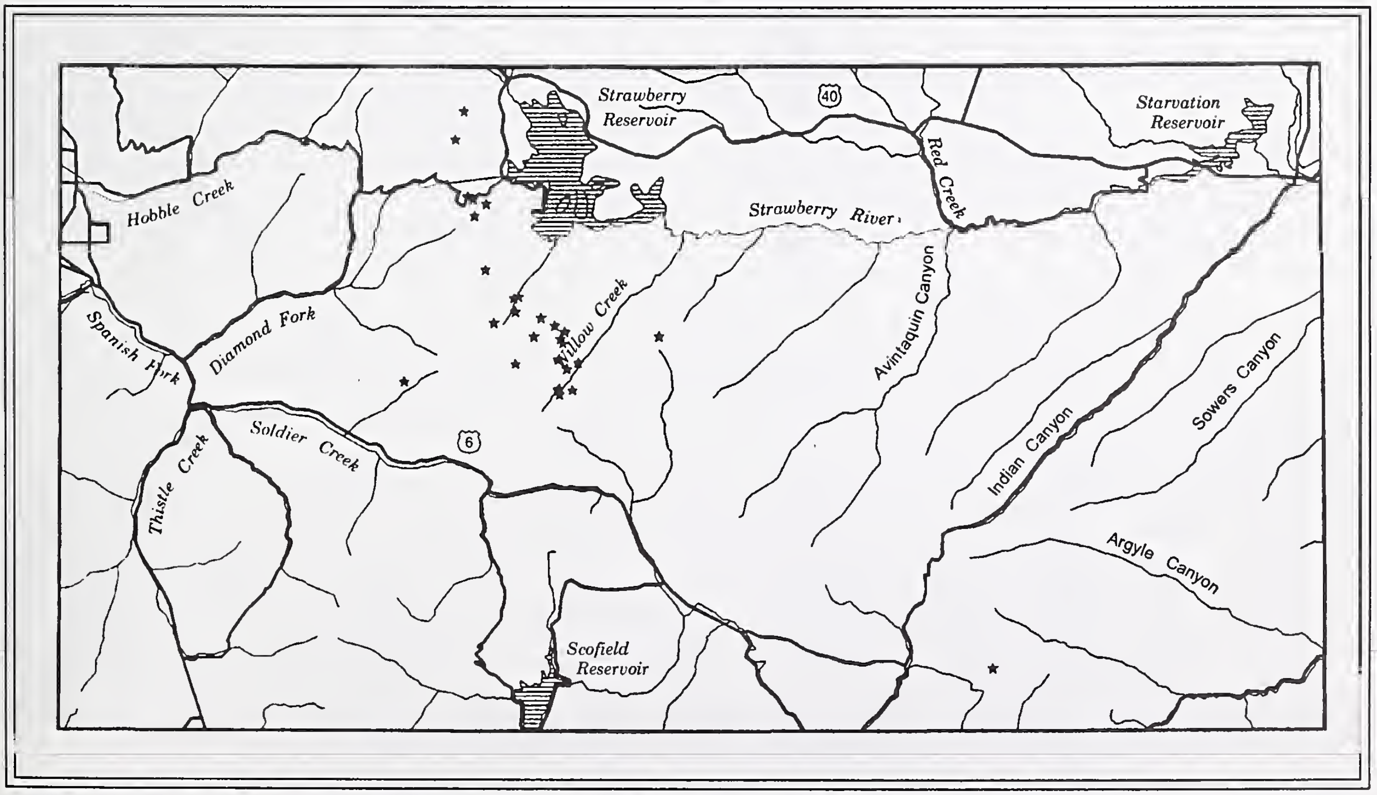


Figure 8—Locations on 3 June 1994 of cow elk collared in Willow Creek and on Strawberry Ridge. Elk at these locations were considered to be inhabiting calving grounds.

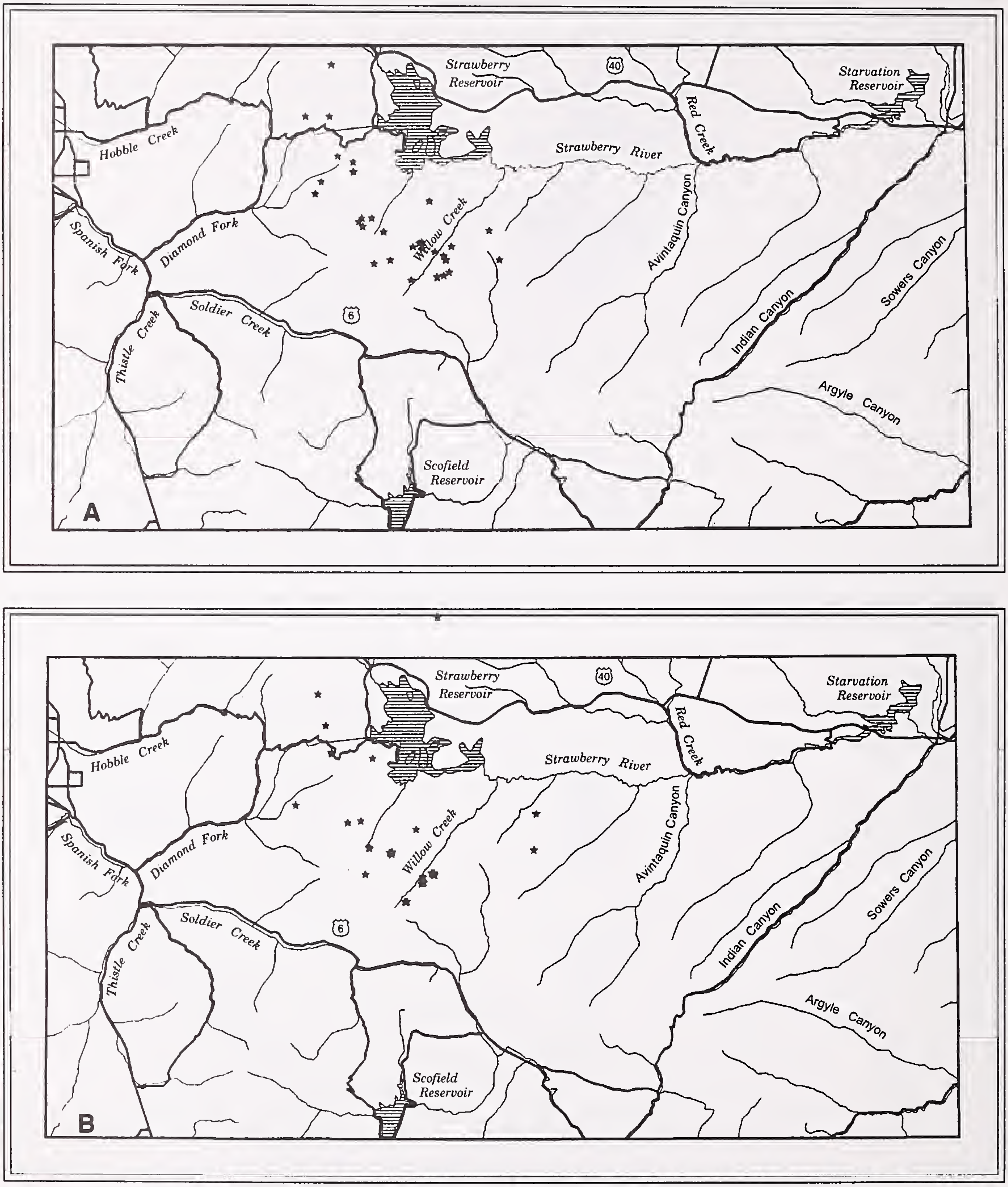


Figure 9—Locations on 24 August 1993 (A) and 12 August 1994 (B) of cow elk collared in Willow Creek and on Strawberry Ridge. Elk at these locations were considered to be inhabiting summer range.

Population Density Estimates of Elk

Otis and others (1978) detailed methods for censusing closed animal populations. The basic premise of their methods was to mark individuals and then trap the population of interest to recapture marked individuals to obtain a ratio of marked to unmarked animals in the population. These data were then used to extrapolate a population size for the population of interest. Otis and others (1978) suggested that marked animals could be observed rather than trapped to obtain a ratio of marked to unmarked animals.

After collars were placed on elk cows in July 1993, the number of collared cows in classified elk herds was recorded to obtain a ratio of marked to unmarked elk. Five fewer radio-collared cow elk existed during the October 1993 and May and June 1994 census due to previous harvesting. Elk populations during these months were based on 25 radio-collared cow elk instead of 30. The total data were computed into the Lincoln Index (Lincoln 1930) to calculate monthly population densities for the Willow Creek drainage. Data were averaged by month as the premise for a closed population.

Results of the 1993 monthly Lincoln Index indicate a mean of 900 (SE = 211) elk (table 4). These data grant 95 percent confidence that the true estimated mean lies between –6 and 1,806 elk. Results of the 1994 monthly Lincoln population index gave a mean of 686 (SE = 202) (table 4). This provides 95 percent confidence that the true estimated mean elk population lies between 124 and 1,247. In 1994, the Lincoln Index was calculated with data from Utah Division of Wildlife Resources aerial flights to obtain a monthly population estimate. The 1994 Lincoln aerial monthly index yielded a mean of 429 (SE = 130). This means that one can give 95 percent confidence that the true estimated mean lies between 94 and 765 elk (table 4). Standard error values for the 1993 and 1994 monthly Lincoln Index population estimates demonstrated that these data were so variable that the estimated means are not reliable.

On 1993 and 1994 aerial flights conducted by the Utah Division of Wildlife Resources, elk cows collared in the Willow Creek drainage were located and elk with those collared cows that could be clearly observed were counted (C. Clyde 1993, 1994, personal communication). The number of elk observed with collared cows was used to calculate a ratio. These data were then used to determine the average number of elk with each collared cow. The results for August, September, and October 1993, and, May through October 1994 are listed in table 4. Five fewer radio-collared cow elk existed during the October 1993 and May and June 1994 flights due to previous harvesting. Thus, the elk populations during these months were based on 25 radio-collared cow elk instead of 30.

In 1993, an average of 393 (SE = 91) elk were estimated via the aerial census. The standard error indicates that one can have 95 percent confidence that the true estimated mean lies between 1 and 786 elk. In 1994, an average of 383 (SE = 92) elk were estimated from aerial flight censuses. The standard error of 92 gives 95 percent confidence that the true estimated mean lies between 148 and 619 elk. The variation observed in the aerial sampling procedure used was much less than that for Lincoln Index estimates of elk density (table 4), therefore more confidence was found in aerial estimates of elk population densities in the study area.

With all the methods used to estimate elk population density, it must be realized that estimates were made in relationship to the Willow Creek drainage and based on the 30 (or 25 as described) collared cows

Table 4—Mean monthly population estimates of elk in the Willow Creek study area, 1993 and 1994.

	1993		1994		
Month	Lincoln index	UDWR[a] aerial flights	Lincoln index	UDWR[a] aerial flights	Lincoln index of UDWR[a] aerial flights
May			300	279	272
June			568	214	195
July	1,320		780	600	673
August	721	568	1,420	342	320
September	660	261	360	149	154
October		350		713	962
Mean	900	393	686	383	429
SE	211	91	202	92	130
df (n – 1)	2	2	4	5	5
CI (95 percent)	(–6 to 1,806)	(1 to 786)	(124 to 1,247)	(148 to 619)	(94 to 765)

[a] These estimates included elk cows originally collared in the Willow Creek study area that had moved out of the study site, therefore, they do not indicate elk density in Willow Creek.

in an assumed closed population. Closed populations are based on time intervals, with the assumption that nonsignificant amounts of mortality, emigration, or immigration occurs during defined periods. The assumption of a closed population cannot be made for the study area because some of the 30 radio-collared elk were outside of the Willow Creek study area following attachment of collars. Actual areas for which these population density values were estimated are greater than the 100.1 km^2 of the study area due to movements of collared elk in and out of the study area (maps 1 through 3). Therefore, these estimates of elk population density are not exclusive to the Willow Creek study area.

C. Clyde and the contractors that captured elk using a helicopter roughly estimated 350 to 450 elk in the study area on 22 and 23 July 1993 (C. Clyde 1993, personal communication). The elk capture crew thoroughly surveyed the Willow Creek study area to proportionately distribute collars on elk within the study area. But Clyde, on reflection, felt the population of elk in the study area at that time was probably closer to 400.

Elk Classifications and Population Structure

A total of 3,687 elk were classified from May to October 1993 (1,597) and 1994 (2,090) (table 5). A cow-to-calf ratio from a standard period of 15 July to 1 October (when calves were best visible and before the disruption caused by the rifle elk hunt) resulted in 49 calves per 100 cows in 1993 and 54 calves per 100 cows in 1994 (table 5). These data closely agree with the Utah Division of Wildlife Resources (1994), 5 year (1989 to 1993) prehunt cow to calf ratio trend (average) of 48 calves per 100 cows in the Diamond Fork/Strawberry elk unit. Near Estes Park in north-central Colorado, Bear (1989) reported a mean winter ground count of 46 calves per 100 cows during 2 years when hunting mortality was not significant (1979 and 1981). Craighead and others (1973) observed a calf-to-cow ratio during summer in Yellowstone National Park of 31 calves per 100 cows in 1970 and 38 calves per 100 cows in 1971. Bear (1989) hypothesized that more vegetation is available to elk during milder winters with less snow, and this gives cow elk a higher nutritional plane that results in higher calf-to-cow ratios. Bear suggested that quality winter nutrition would result in larger calves being born, and thus result in higher calf elk survival. The increase of five additional calves per 100 cows in 1994 more than in 1993 can probably be explained best through weather phenomena because the 1993-1994 winter was more mild than the 1992-1993 winter, thus providing gestating cows more quality forage.

A cow-to-bull ratio calculated in 1993 from the same standard period (15 July to 1 October) revealed a ratio of 14 bulls to 100 cows, and in 1994, of 15 bulls to 100 cows (table 5). This was slightly lower than the average of 16 bulls per 100 cows classified before the rifle elk hunt by the Utah Division of Wildlife Resources (1994) in this herd unit between 1989 and 1993. In 1993, 10 (71.0 percent) of the 14 bulls were immature and four (29.0 percent) were mature. Since 1992, this elk herd unit has been open to yearling-only bull elk hunting. The 1993 immature-to-mature bull ratio shows some improvement over the 1991 (last year of open bull elk hunting) Diamond Fork/Strawberry bull elk classification data that found that 79 percent of classified bulls were yearlings and 21 percent were mature bulls (Utah Division of Wildlife Resources 1992). In 1994, 86 to 93 percent of bulls were immature and the remaining bulls (7 to 14 percent) were mature (table 5). In 1994, more mature bulls were seen before 15 July, with an observed high of five mature bulls in

Table 5—Elk classification ratios[a] for the period 15 July to 1 October 1993 and 1994[b], in the Willow Creek study area. Total elk sampled in the study area in 1993, 1994, and both years combined.

Year	Calves: cows	Immature bulls: cows	Mature bulls: cows	Total bulls: cows	Total elk
1993					1,597
Ratio	49:99	9:99	4:99	13:99	
Per 100	50:100	10:100	4:100	14:100	
1994					2,090
Ratio	134:251	33:251	4:251	37:251	
Per 100	54:100	14:100	2:100	15:100	
Combined					3,687

[a] Herds of greater than 5 cow elk with less than 20 percent calves were not figured into these ratios. At times, these observations were during afternoon hours and were assumed to indicate the fact that calves bed during the day, thus, their presence may have been lacking.

[b] Includes 11 elk classified in Trail Hollow (adjacent to the study area) on 23 August 1994.

a herd of 32 elk in unit 1 of the McKinney allotment on 4 July (map 2).

Mature bulls contribute to the reproductive success of elk herds. At Hardware Ranch in northern Utah, captive yearling bulls impregnated about 6.3 percent fewer cows than captive mature bulls. Cow elk normally responded agonistically to copulatory attempts by immature bulls (Prothero and others 1979). Conception and calving dates were 4 to 6 weeks later in cows bred by immature bulls than cows bred by mature bulls (Prothero and others 1979). Squibb (1985) studied the mating success of wild elk at Hardware Ranch where mature bulls were rare. Mature bulls performed 76 percent (in 1980) and 70 percent (in 1981) of complete mounts even though they were less than 25 percent of the bulls present. These percent values were greater than randomly expected (Squibb 1985). More cow elk will be bred and produce calves earlier by maintaining mature bulls in the Diamond Fork/Strawberry herd unit. This should result in larger calves who will be more capable of surviving winter conditions.

Because no bachelor herds (all-male herds) were found in the drainage from June to August 1993, all elk herds classified during this period were considered nursery herds (maps 1 and 3). The only all-male elk herd observed consisted of four yearling bulls in unit 2 of the McKinney allotment on 17 August 1994. Therefore, it seems warranted to define all classified elk herds in July and August 1994 as nursery herds (maps 1 and 2).

Mean elk herd size in 1993 was 24.2 (SD = 39.5) and in 1994 was 34.7 (SD = 47.3) (table 6). Elk herd numbers in both years were smallest in spring, largest in summer, and decreased again in fall (table 6). Mackie (1970) reported that elk herd sizes on the Missouri River Breaks in Montana were average in spring, decreased slightly in summer, and were highest in fall. The largest elk herd size was in summer 1994 (mean = 56.1, SD = 59.2); the herd size in spring 1993 was the smallest (mean = 7.3, SD = 8.0) (table 6). Only twice were elk herds greater than 200 elk, and this was once each in both summers. Elk herd sizes were usually from 1 to 10 individuals (table 7). There

Table 6—Mean seasonal herd size of elk in the Willow Creek study area, 1993 and 1994.

Year	n	Mean	SD	Minimum	Maximum
1993					
Spring	14	7.3	8.0	1	23
Summer	41	31.5	46.8	1	265
Fall	8	16.4	15.4	1	43
Total	63	24.2	39.5	1	265
1994					
Spring	28	14.4	17.2	1	85
Summer	29	56.1	59.2	4	230
Fall	3	16.0	4.6	12	21
Total	60	34.7	47.3	1	230

Table 7—Percent of elk herds in size intervals in the Willow Creek study area, 1993 and 1994.

		Elk herd size intervals					
Year	n	1-10	11-25	26-50	51-100	101-200	≥201
1993							
Spring	14	78.6	21.4	0.0	0.0	0.0	0.0
Summer	41	43.9	19.5	14.6	14.6	4.9	2.4
Fall	8	37.5	25.0	37.5	0.0	0.0	0.0
Total	63	50.8	20.6	14.3	9.5	3.2	1.6
1994							
Spring	28	57.1	21.4	17.9	3.6	0.0	0.0
Summer	29	24.1	24.1	13.8	17.2	17.2	3.4
Fall	3	0.0	100.0	0.0	0.0	0.0	0.0
Total	60	38.3	26.7	15.0	10.0	8.3	1.7

were never any herds larger than 50 elk in the fall, and in fall 1994 all three elk herds sampled were from 11 to 25 in number. There were no sampled elk herds more than 26 individuals in spring 1993. In spring 1994, however, 21.5 percent of elk herds were between 26 and 100 animals (table 7).

Elk Use of Habitats

In 1993, behavioral and ecological data were collected from elk observed at 63 sites from 20 May to 1 October. One of these locations was adjacent to the study area in unit 3 of the Beaver Creek allotment. All 63 locations plus nine (two of these on Poison Ridge) other 1993 elk locations (72 total) appear on maps 1 and 3. In 1994, elk behavioral and ecological data were assessed from 60 elk locations observed from 10 May to 28 September (maps 2 and 3). Elk location site data included evaluations such as: date, time, slope, aspect, elevation, temperature, and sky condition. Ecological factors included estimated distances to horizontal obscurity cover in the four cardinal directions, plant community type, and distances to habitat edge, sheep salting placements or natural mineral licks, roads, sheep, and human activity. Behavioral categories recorded included herd size, classification of the herd (that is, by sex, age, or unclassified), and 16 known elk behaviors ranging from walking, calf nursing, and eating soil.

Elk locations in relation to distances from macroecological factors revealed how elk utilized Willow Creek habitat. For those factors occurring less than or equal to 1,000 m from individual elk locations (and averaging the distance to the nearest measured feature) in 1993, elk were found to be 21.1 m (SD = 24.4) from a habitat edge, 162.2 m (SD = 162.8) from a ridgetop, 473.3 m (SD = 304.4) from water, 396.5 m (SD = 310.1) from a road, 825.0 m (106.1) from sheep, 93.0 m (SD = 95.0) from mule deer, 251.7 m (SD = 179.3) from a salting location or natural mineral source, and 630.0 m (SD = 385.6) from humans (appendix D, table D1). On only two instances were elk found less than 1,000 m from sheep (appendix D, table D1). Both of these instances occurred as elk were utilizing salting sources near current sheep locations at the time of observation. At seven locations elk were found less than or equal to 1,000 m from human activity in 1993. Three (42.9 percent) of these times, elk were less than or equal to 1,000 m from the Willow Creek guard station (maps 1 and 3). Four or 57.1 percent of these times elk were less than or equal to 1,000 m from a sheepherders camp.

For those factors occurring less than or equal to 1,000 m from individual 1994 elk locations (and averaging the distance to the nearest measured feature), elk were found to be 35.8 m (SD = 61.7) from a habitat edge, 108.7 m (SD = 104.7) from a ridgetop, 477.1 m (SD = 280.5) from water, 429.7 m (SD = 304.2) from a road, 161.6 m (SD = 140.5) from mule deer, and 387.9 m (SD = 294.6) from a salting location or natural mineral source (appendix D, table D1). On only one occasion were elk found less than or equal to 1,000 m from sheep (621.0 m) in 1994, and on two occasions they were less than or equal to 1,000 m from humans (mean = 430.5 m, SD = 405.2; once was less than or equal to 1,000 m from the guard station and once was less than or equal to 1,000 m from a sheep camp) (appendix D, table D1; maps 2 and 3).

On the average, in 1993 and 1994, elk were closer to a habitat edge, ridgetop, and salting or natural mineral source than were sheep. On the other hand, elk were farther from roads and humans than sheep were in 1993 and 1994 (appendix D, table D1). Elk were farther from water than sheep were in 1993, but closer to water than sheep were in 1994 (appendix D, table D1). This may reflect the fact that 1994 was a much drier year than 1993, and elk were thus concentrated more around water sources.

Elk were at slightly higher elevations in summer (1993 mean = 2,720.1 m, SD = 103.8; 1994 mean = 2,688.1 m, SD = 82.3) versus spring (1993 mean = 2,691.7 m, SD = 48.2; 1994 mean = 2,677.1 m, SD = 66.3) (table 8). Elk used more southeast-, south-, southwest-, and west-facing exposures in spring (1993 = 71.4 percent; 1994 = 67.8 percent) and began using more north-, northeast-, east-, and northwest- sloping habitats in the summer (1993 = 46.3 percent; 1994 = 51.6 percent). By fall the majority of aspects used were north, northeast, east, and northwest (1993 = 75.0 percent; 1994 = 66.6 percent) (table 8). In spring 1993, elk were located 35.7 percent of the time on slopes less than or equal to 10° and in spring 1994, 67.9 percent of elk locations were on slopes less than or equal to 10°. In summer, elk were found 41.4 percent of the time on slopes greater than or equal to 11° in 1993, and in 1994, 58.6 percent of elk locations occurred on slopes greater than or equal to 11°. By fall (1993 = 100.0 percent; 1994 = 66.6 percent) of elk locations in the study area occurred on slopes greater than or equal to 11° (table 8).

Differences in elk use of various components in their habitat can be explained on a seasonal basis (table 8, appendix C, table C1, and appendix D, table D1). Elk were usually closer to mean horizontal obscurity cover in the spring (1993 mean = 62.5 m, SD = 40.2; 1994 mean = 108.8 m, SD = 120.3) and fall (1993 mean = 79.1 m, SD = 35.6; 1994 mean = 23.3, SD = 19.4) than in summer (1993 mean = 131.6 m, SD = 115.6; 1994 mean = 65.3 m, SD = 72.6) (appendix D, table D1). In 1993, elk were an average distance of 441.3 m (SD = 289.0) in spring, 474.9 m (SD = 270.7) in summer, and 394.8 m (SD = 274.3) in fall from a source of water. In 1994, elk were an average distance of 560.6 m (SD = 272.5) in spring, 408.0 m (SD = 274.4) in summer, and 520.7 m (SD = 327.4) in fall from a source of water (appendix D,

Table 8—Seasonal sample sizes and percents of aspect and slope use and mean elevation (m [ft in parentheses]) of locations of elk and domestic sheep, 1993 and 1994.

		Aspect								Degree of slope			Elevation (m)	
Season	n	N	NE	E	SE	S	SW	W	NW	0-10	11-25	≥26	Mean	SD
Elk 1993														
Spring	14	0.0	7.1	21.4	28.6	14.3	7.1	21.4	0.0	35.7	64.3	0.0	2,691.7 (8,825.4)	48.2
Summer	41	2.4	9.8	7.3	9.8	9.8	24.4	9.8	26.8	58.5	39.0	2.4	2,720.1 (8,918.2)	103.8
Fall	8	0.0	25.0	0.0	0.0	0.0	12.5	12.5	50.0	0.0	100.0	0.0	2,706.1 (8,872.5)	54.0
Total	63	1.6	11.1	9.5	14.3	7.9	19.0	12.7	23.8	46.0	52.4	1.3	2,712.0 (8,891.7)	88.8
Elk 1994														
Spring	28	3.6	14.3	7.1	14.3	14.3	32.1	7.1	7.1	67.9	28.6	3.6	2,677.1 (8,777.4)	66.3
Summer	29	3.4	24.1	10.3	20.7	3.4	20.7	3.4	13.8	41.4	55.2	3.4	2,688.1 (8,813.4)	82.3
Fall	3	0.0	33.3	0.0	33.3	0.0	0.0	0.0	33.3	33.3	33.3	33.3	2,725.8 (8,937.0)	18.1
Total	60	3.3	20.0	8.3	18.3	8.3	25.0	5.0	11.7	53.3	41.7	5.0	2,685.0 (8,802.7)	73.8
Sheep 1993														
Summer	18	11.1	16.7	5.6	5.6	5.6	11.1	5.6	38.9	66.7	33.3	0.0	2,728.2 (8,944.9)	100.5
Fall	14	0.0	42.9	0.0	14.3	14.3	14.3	0.0	14.3	42.9	57.1	0.0	2,697.8 (8,845.1)	91.8
Total	32	6.3	28.1	3.1	9.4	9.4	12.5	3.1	28.1	56.3	43.8	0.0	2,715.0 (8,901.2)	96.5
Sheep 1994														
Summer	25	4.0	28.0	0.0	20.0	0.0	16.0	0.0	32.0	48.0	48.0	4.0	2,717.2 (8,908.9)	95.6
Fall	9	0.0	44.4	0.0	22.2	0.0	0.0	0.0	33.3	44.4	55.6	0.0	2,718.2 (8,912.0)	112.2
Total	34	2.9	32.4	0.0	20.6	0.0	11.8	0.0	32.4	47.1	50.0	2.9	2,717.5 (8,909.7)	98.5

table D1). Of those locations where elk were less than 1,000 m from a road, they were closer to a road in summer (1993 mean = 395.0 m, SD = 330.2; 1994 mean = 367.3 m, SD = 262.4) than in fall (1993 mean = 482.3 m, SD = 290.7; 1994 mean = 669.0, SD = 405.9). Elk were closer to a road in spring 1993 (1993 mean = 339.2 m, SD = 260.2) than in spring 1994 (mean = 457.7 m, SD = 326.7) (appendix D, table D1).

While studying the use of roads by a western Montana elk herd, Marcum (1976) found open system roads were used significantly less than their availability, use of open spur and four-wheel drive trails did not differ significantly from availability, and closed roads were used significantly in excess of availability. A similar relationship was observed in elk on the Willow Creek drainage. Most seemed to distance themselves from the main (open system) roads in the southwestern portion of the study area, especially as the hunting seasons progressed in the fall (maps 1 and 2). For sampled elk locations less than or equal to 1,000 m from a road in fall 1993 and 1994, 50.0 percent of elk were greater than or equal to 404 m (0.25 mile) from a road (appendix D, table D1).

During and after the increased human activity and use of roads during the fall hunting seasons, most Willow Creek elk traveled to those areas farthest from roads (maps 1 and 2). The Utah Division of Wildlife Resources Loran elk locations on maps 1 and 2 show that in fall elk moved to areas farthest from roads. Map 3 and appendix C, table C1 indicate the change in plant communities used by elk during fall. At this time, elk were found in the more forested and shrubby communities (aspen, aspen-conifer, conifer, snowberry, and mixed brush types) more often than previously observed before the hunting season.

Basile and Lonner (1979) surveyed Montana elk hunters where vehicle use had been recently restricted on the Judith River area of the Lewis and Clark National Forest and the Ruby River area of the Beaverhead National Forest. They found the Judith River area with a two-thirds forested covering had a 28 percent increase in the numbers of elk both seen and killed per hunter. The Ruby River area, comprised essentially of open grassland with scattered islands of timber, experienced a marked increase through the hunting seasons in the uniformity of sightings and kills. These responses were attributed mainly to differences in total forest cover. In a study of elk use of Alberta grassland and forested habitat, Morgantini and Hudson (1979) reported habitat selection was not strongly related to weather conditions or forage availability. Rather, as a result of January and February hunting season pressures, elk used habitats in the winter in relation to distances from roads. For example, the majority of elk using grasslands were 0 to 800 m from the closest road, and the majority of elk using deciduous forest were 1,600 to 2,400 m from a road. These results mirrored winter elk circadian movements from early mornings in grasslands through shrubland into the habitat farthest from roads (deciduous and coniferous forests) to bed down for the day (Morgantini and Hudson 1979).

While monitoring elk behavior in relation to multiple uses on the Medicine Bow National Forest in southern Wyoming, Ward (1973) concluded that traffic on Forest Service system roads had little effect on elk activity, especially beyond 274.2 m. A table depicting the distances of two radio-collared cow elk in this study revealed these two elk were more often from 274.2 m to 1.61 km away from roads. Elk preferred to be at least 810 m from people engaged in out-of-vehicle activities such as camping, picnicking, fishing, and harvesting timber. The 630.0 m (SD = 385.6) average distance of elk less than or equal to 1,000 m from human activity in 1993 and 430.5 m (SD = 405.2) average distance of elk less than or equal to 1,000 m from humans in 1994 appear to be a function of the number of roads, giving more access to human activity (appendix D, table D1).

Hiding or escape cover is a component of elk habitat that provides elk security or a means of escape from the threat of predators or harassment (Skovlin 1982). According to Thomas and others (1976) sight distance is the horizontal distance into a cover type beyond which a simulated elk or "cover density board" cannot be seen by the human eye. The average distances of elk to this kind of obscurity cover are tabulated in appendix D, table D1. Analyses revealed elk were an average of 109.6 m (SD = 100.2) in 1993 and 83.5 m (SD = 98.9) in 1994 from obscurity cover. This agrees well with the findings of Coop (1971) who found elk fled an average of 114 m from the point of disturbance to a point where they disappeared from view into cover in Douglas-fir, spruce/fir, and open parkland type summer range in central Montana.

Elk Biting Fly Index

The biting fly family, Tabanidae (horse and deer flies), are characterized by females who obtain a blood meal, necessary for egg maturation, from mammals, reptiles, and, on occasion birds, and males who subsist solely on carbohydrates (nectar, sap, and aphid feces) (Bowman 1995). The effect of biting flies (Tabanids) on distributions of herds of elk and other big game mammals has been described by Murie (1951), Brazda (1953), Hibler and Adcock (1971), and Kistner and others (1982). Livestock in pastures with numerous flies can be harassed by biting flies to such a great extent they cannot rest or graze adequately, which interferes with production and can prove fatal (Bowman 1995).

Mosquitos were never plentiful in the study area. Biting flies became prevalent in Willow Creek about mid-July, and high populations persisted for about 1 month in 1993. In 1994, biting flies became prevalent earlier in the season, and their presence persisted into early September before the first heavy frosts. By comparison, the biting fly season continued from 13 July to 21 August in Brazda's (1953) study of elk migration in the Gallatin River drainage in Montana. Brazda concluded that an inverse relationship between Tabanid numbers and elk numbers existed in his study area. Adams (1982) concluded that insects influence daily movements, activities, and distribution of elk on summer ranges, but generally, at most, have a minimal impact on the timing or speed of autumn or spring migrations.

Twenty biting fly indices were performed at elk locations from 30 June to 3 September 1994 (map 2). The most common elk reactions to fly attacks to the head and neck were continual ear twitching and head tossing. Elk licked at flies at two sites, and elk scratching was seen at one site where a biting fly index was conducted. Ralley and others (1993) studied effects of biting flies on cattle heifers in eastern Manitoba and observed a significant increase in individual foot stomps, head tosses, and tail switches due to horseflies and mosquitos. Two gelding horses, used as biting fly index monitors in the Willow Creek study, used a variety of methods to keep biting flies off their bodies including muscle contractions, foot stomping, tail and mane swishing, and ear twitching. Sheep in the study area were never observed to suffer any noticeable effects from biting flies.

The number of biting flies observed during the sampling period is noted by site (map 2) and in tabular form in table 9. The two smallest counts of 27.0 and 21.0 flies occurred at those sites that were the second (more than 1,000 m) and third (897.0 m) farthest, respectively, from water (table 9). Biting fly indices sampled in riparian zones had the largest number of flies (mean = 134.7, SD = 172.3) (table 9). Elk used riparian areas earlier in the day (mean = 1024.0 hours, SD = 104.9) presumably to avoid high fly levels near water during warm afternoon hours. These observations of elk moving away from high fly densities near water agree with Bowman (1995) who noted that Tabanid flies are always concentrated around water, except for a few xerophilic species.

The number of biting flies counted at all 20 index locations were regressed against several environmental variables chosen from a regression selection procedure including the time of day, cosine of aspect°, sine of aspect°, temperature (C), slope°, and date of sampling. These variables are all attributed to fly activity and are discussed in this section. The coefficient of determination (R^2) reveals the proportion of variablity in dependent variables that can be accounted for by independent variables (Ott 1993). The combination of these predictors resulted in an R^2 of 0.80 (df = 19, P = 0.001) (table 10). This means 80 percent of the variability in numbers of flies counted at indices was explained through variables (predictors) in the regression equation. All of these variables (except time of day) contributed significantly ($P < 0.05$) to the regression equation (table 10). The degree of aspect had the greatest effect on biting fly numbers. The coefficient for cosine of aspect° suggests that north-south aspects

Table 9—Measurements conducted at biting fly index locations (30 June to 3 September 1994) by plant community and in relation to weather and habitat variables.

Plant community	n	Flies		Time (in hours)[a]		Temp °C		Beaufort scale[b]		Sky condition[c]		Distance ≤1,000 (m) Ridgetop		Distance ≤1,000 (m) Water	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Aspen-grass	2	128.0	97.6	1626.5	9.2	25.0	2.8	1.5	1.0	1.5	0.7	169.0	36.8	380.5	208.6
Aspen-snowberry	5	87.8	102.4	1496.4	240.7	23.4	3.1	1.6	1.0	1.2	0.8	89.8	66.4	658.0	425.3
Grass-meadow	4	95.8	66.4	1419.8	451.9	20.3	3.8	1.8	1.0	1.0	1.4	56.3	68.0	453.3	213.4
Mixed brush	1	54.0	0.0	1931.0	0.0	20.0	0.0	4.0	0.0	3.0	0.0	6.0	0.0	489.0	0.0
Mixed brush-grass	1	21.0	0.0	829.0	0.0	16.0	0.0	1.0	0.0	0.0	0.0	103.0	0.0	897.0	0.0
Riparian	3	134.7	172.3	1024.0	104.9	22.0	1.0	1.7	1.0	1.0	1.0	102.7	85.5	23.3	21.1
Sage-*Ch vis*-grass	1	27.0	0.0	1415.0	0.0	25.0	0.0	3.0	0.0	1.0	0.0	175.0	0.0	>1,000.0	0.0
Snowberry	1	62.0	0.0	1228.0	0.0	26.0	0.0	2.0	0.0	2.0	0.0	206.0	0.0	1,183.0	0.0
Snowberry-grass	2	85.5	79.9	1675.5	361.3	25.0	0.0	2.0	1.0	0.5	0.7	79.0	53.7	309.5	402.3

[a] Military time (0000 to 2400 hours).

[b] Beaufort Scale of wind force and equivalents. Rating scale is as follows: 0 = calm = 1 mph; 1 = light air = 1-3 mph; 2 = light breeze = 4-7 mph; 3 = gentle breeze = 8-12 mph; 4 = moderate breeze = 13-18 mph; 5 = fresh breeze = 19-24 mph; 6 = strong breeze = 25-31 mph; 7 = moderate gale = 32-38 mph; 8 = fresh gale = 39-46 mph; 9 = strong gale = 47-54 mph; 10 = whole gale = 55-63 mph; 11 = storm = 64-75 mph; and 12 = hurricane = >75 mph.

[c] Sky Condition. Rating scale is as follows: 0 = clear, 10 percent cloud cover; 1 = scattered, 10 to 50 percent cloud cover; 2 = broken, 50 to 90 percent cloud cover; 3 = overcast, 100 percent cloud cover; 4 = fog, smoke, dust (visual obscuration); 5 = rain; and 6 = snow.

Table 10—Multiple regression of the number of biting flies at 20 elk locations sampled from 30 June to 3 September 1994 on habitat variables indicative of biting fly numbers. These data were initially subjected to best subsets of regression to choose the best model.

Predictor	Coefficient	SE	*P*	R^2	df	*F*	*P*
				0.80	19	8.73	0.001
Constant	46.810	13.180	0.004				
Aspect° (Sine)[a]	2.976	1.238	0.032				
Aspect° (Cosine)[a]	3.314	0.936	0.004				
Date	–0.213	0.050	0.001				
Temperature (C)	0.513	0.164	0.008				
Time of day	0.003	0.002	0.209				
Slope°	–0.550	0.103	0.000				

[a] The degree of aspect at elk biting fly index locations were sine and cosine transformed. Because sine and cosine are cofunctions of each other, it follows that the cofunctions of complementary angles are equal (Smith 1991). Sine transformations pertain to east-west aspects. Cosine transformations pertain to north-south aspects.

had a greater effect on biting fly numbers than any other variable (table 10).

Collins and Urness (1982) reported that tame, captive elk relocated from feeding in meadow bottoms to forested areas due to a temperature lag, attributed to shading, which delayed fly activity by less than or equal to 1.5 hours. In Willow Creek, seven (35.0 percent) of the total elk biting fly indices were sampled in aspen community types (table 9). This may indicate the movement of elk to the cooler microclimate (fewer flies) afforded by tree cover in summer. Elk also seemed to move vertically and laterally to areas (for example, windy ridges, north and east aspects, and away from lower riparian areas) suspected to be less frequented by flies during the diurnal hours of summer (maps 1 and 2, tables 8 through 10, and appendix D, table D1). For example, in summer, elk were situated an average of 176.5 m (SD = 173.4) in 1993, and 103.1 m (SD = 102.4 m) in 1994 from a ridgetop, which was slightly closer than in spring or fall (appendix D, table D1). By comparison, the index with the highest elevation (2,760.6 m) (table 11) also had the third lowest numbers of flies (54.0) and was closer to a ridegetop (6.0 m) than any other index (table 9).

At this site, the Beaufort scale of wind force and equivalents was 4, the highest of any location. A Beaufort scale of 4 is defined as a moderate breeze with wind speeds of 13 to 18 mph (Society of American Foresters 1955). By comparison, Johnson (1951) related that insect infestations appeared to be a major nuisance to elk occupying the Gallatin River drainage in Yellowstone National Park during July and August. This caused elk to inhabit high windy ridges to escape harassment. Similarly, Downes and others (1986) reported herds of mountain caribou (*Rangifer tarandus caribou*) in the southwestern Yukon traveled

Table 11—Percents of aspect and slope use and mean elevation (m [ft in parentheses]) of elk biting fly index locations by plant community, 1994.

Plant Community	Aspect								Degree of slope			Elevation (m)	
	N	NE	E	SE	S	SW	W	NW	0-10	11-25	≥26	Mean	SD
Aspen-grass	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	50.0	50.0	0.0	2,720.0 (8,918.0)	57.4
Aspen-snowberry	0.0	40.0	0.0	0.0	0.0	20.0	0.0	40.0	0.0	100.0	0.0	2,725.1 (8,934.8)	84.4
Grass-meadow	0.0	25.0	0.0	50.0	0.0	25.0	0.0	0.0	75.0	25.0	0.0	2,726.1 (8,938.0)	46.4
Mixed brush	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	2,760.6 (9,051.0)	0.0
Mixed brush-grass	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	2,739.5 (8,982.0)	0.0
Riparian	0.0	33.3	33.3	0.0	0.0	0.0	0.0	33.3	66.7	33.3	0.0	2,534.1 (8,308.7)	61.2
Sage-*Ch vis*-grass	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	2,662.7 (8,730.0)	0.0
Snowberry	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	2,659.6 (8,720.0)	0.0
Snowberry-grass	0.0	50.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	50.0	50.0	2,646.9 (8,678.5)	68.4

significantly more to upper slopes and ridgetops in relation to increasing mosquito (Culicidae) populations to escape higher levels of mosquito parasitism at lower elevations. They also reported that during the year (the driest year studied) of highest mosquito and bot fly (Oestridae) levels, caribou significantly used snow patch and unvegetated microhabitats.

Adams (1982) suggested an elk behavioral response to peak insect activity was resting in the cool microclimate of tall meadows during the warmest daylight hours. Johnson (1951) reported that elk of the Gallatin River herd in Yellowstone National Park apparently attempted to avoid insect attacks by bedding down in tall sedge meadows. Espmark and Langvatn (1979) reported that tame, adult, red deer (*Cervus elaphus elaphus*) hinds were observed to lie down 33 percent of the time during periods when head fly (*Hydrotaea irritans*) harassment was nil and 71 percent during days of severe head fly harassment. Regarding the number of ear flips per minute when these deer were grazing and when they were bedded, after the deer were down for 15 minutes, the frequency of ear flips stabilized at approximately 50 percent of the initial, standing frequency. The difference in ear flip frequencies was statistically significant suggesting that to reduce harassment by flies, inactivity may be an important behavior in red deer (Espmark and Langvatn 1979).

Coinciding with these data, elk in Willow Creek engaged in this type of behavior to avoid Tabanid attacks by lying down in grassy areas. Consequently, 10 (50.0 percent) of the elk biting fly indices were in grassy plant communities (aspen-grass, grass-meadow, mixed brush-grass, sagebrush-*Chrysothamnus viscidiflorus*-grass, snowberry-grass). Often, elk were at these locations during the warm daylight hours (table 9).

Tremendous parasitism can be applied by biting flies. Tashiro and Schwardt (1953) reported that on a typical summer day in northern New York, a horse may be bitten by nearly 4,000 Tabanid flies, and these bites may constitute a loss of up to 0.5 liter of blood. Collins and Urness (1982) reported their tame elk attracted three times as many horseflies as their tame mule deer, and when one elk harassed by horseflies ran, this stimulated all other elk in the herd to run. When attacked by biting flies, group formation of grazing lines and bunching were the most prevalent responses in herds of cattle studied by Ralley and others (1993) in Manitoba.

Mooring and Hart (1992) theorized that grouping frequently reduces per capita fly attacks through the dilution effect, provided that the increase in herd size does not increase the probability of being detected (encounter effect). As a result, animals may remain congregated during the day to dilute the effect of nonvisual hunting flies, and those individuals at the center of herds would therefore be most benefitted (Mooring and Hart 1992). This agrees with Hamilton's (1971) concept that "selfish herding" should offer security from predation as well as parasitism (Mooring and Hart 1992).

Female and juvenile elk in the study area may, theoretically, remain in large nursery herds during summer as a means to cooperatively combat predation by carnivores and parasitism by sanguivorous (blood eating) insects through the dilution effect and by elk monitoring the predator and parasitism avoidance behaviors of their herd companions. Anderson and others (1974) indicated that high CO_2 and body heat levels attract flies to animals. Consequently, dry wallow areas (map 2) identified in 1994 may assist herds of elk in the study area to avoid detection by flies when they are under or adjacent to aspen or tall herb cover and close to ridgetops, allowing elk to keep cool, resulting in lower body heat and reduction in CO_2 output because elk are not respiring greatly while resting. Dust may also close the spiracles (breathing holes) of insects, which is considered to be the most important function of dusting. Bowman (1995) concluded that the best solution to Tabanid attack was to stable livestock during peak fly activity.

In conclusion, it appears that in the study area the effect of biting flies (and conceivably mammalian predators) on summer elk movements may be as important by comparative degree as the effect of herding on sheep movements in summer, with elk in effect "stabling" themselves in more predation-free microhabitats.

Domestic Sheep Movement Patterns

Domestic sheep movements to, from, and within the Willow Creek area reflect the fact that sheep use this rangeland seasonally and are trailed to and from private land at lower elevations. In fall, lambs are shipped from the corrals, in particular, the corral in Racetrack Hollow (map 2), for marketing. Another factor concerning sheep movements is that the Willow Creek drainage is part of a historic sheep trail, routing sheep to the Strawberry Valley and Strawberry Ridge from Spanish Fork Canyon. A large sheep trail can be seen entering Willow Creek Ridge from the headwaters of the Left Fork of the White River in unit 2 of the McKinney allotment. As a result, much activity associated with sheep production in this region occurs in the drainage and near the Racetrack Hollow Corral.

Domestic sheep production figures historically into this area as seen in names on local topographic maps. Trail Hollow, just north of the Willow Creek study area, is the northern extension of the previously described sheep trail. Poison Ridge, east of Trail Hollow, is purported to be the site of plant-induced sheep poisoning occurring one fall (V. Wilson 1993, personal communication). Cabin Springs in the northeast portion of the study area was named after a log cabin once used to store salt for sheep consumption (V. Wilson 1993, personal communication). Likewise, Sheep Creek in Spanish Fork Canyon (south of the study area) must also have been named after some aspect of early sheep use in the area.

Field work in Willow Creek began in both field seasons (1993 and 1994) as soon as entrance into the area was possible to take advantage of data collection on spring elk use. Field work continued until sheep were trailed from the area in mid-October. In 1993, research continued until 15 October, the last date in 1993 that sheep were authorized to be moved from some allotments. In 1994, all sheep were moved out of the study area by 13 October. Field research on sheep range use in the Willow Creek study area ended on 14 October 1994.

Cabin Springs, Road Hollow, McKinney, and Center Canyon sheep were trailed up the White River trail and then northeast along Willow Creek Ridge or northwest to Racetrack Hollow into the respective allotments. As a result of these practices, and within a flexible and reasonable span of a few days, sheep seen prior to entry onto allotments engaging in this trailing pattern along Willow Creek Ridge or in the Racetrack Corrals or Racetrack Hollow flats west of the Willow Creek Guard Station were not considered to be outside their allotment. Due to heavy snows during the 1992-1993 winter, and resultant tardy range readiness and impassable roads, sheep entrance into the Willow Creek drainage was delayed on five allotments in spring 1993.

The Cabin Springs, Center Canyon, Davis, McKinney, and Road Hollow allotments are managed according to a deferred-rotation grazing system that includes two units each. According to this agreement, sheep from these allotments, in 1993, were to be initially stocked in unit 1 of the respective allotments until 20 August. On 21 August, sheep were to be rotated into the second unit of these allotments and remain there until 15 October (map 1). In 1994, sheep in these same allotments were to be initially stocked in unit 2 until 20 August. On 21 August, sheep were to be rotated into the first unit of each of these allotments and remain there until 15 October (map 2).

The Beaver Creek, Pete's Knoll/Broad Hollow, and Ingram allotments are all grazed under a rest-rotation grazing scheme. Pete's Knoll/Broad Hollow contained five units, and the Beaver Creek and Ingram allotments each consisted of three units. This grazing system differs from the deferred-rotation system in that the land area is divided into more units and one unit is rested from grazing each year.

In no instance were more ewes counted in a band than were permitted to graze in an allotment. However, on many occasions sheep were in the wrong unit of the respective allotments. Movement scenarios in each allotment differed from each other and between years. Therefore, detailed accounts of sheep movement activities by allotment are listed in Beck (1996).

Areas With High Use by Domestic Sheep

Some sheep bed grounds along the northwest ridge of unit 5 of the Broad Hollow/Pete's Knoll allotment have been used so heavily that they appear devoid of vegetative cover on the Gap vegetation layer derived from LANDSAT satellite imagery (map 3). This condition was present at two sheep bed grounds in unit 2 of the Cabin Springs allotment (map 3).

Much sheep activity and trailing were centered around the main large stock pond in the SW ¼ of the SW ¼ of Section 9 in unit 4 of the Beaver Creek allotment; Ice Spring in the NW ¼ of the NW ¼ of Section 32 in unit 1 of the McKinney allotment; the main spring and stock pond in the SE ¼ of the NE ¼ of Section 25 in unit 2 of the Davis allotment; and, the large stock pond in the SW ¼ of the SE ¼ of Section 13 in unit 1 of the Davis allotment (maps 1 and 2). Often, vegetation surrounding these watering points received much trampling as animals traveled to water and then rested nearby during the day. An additional factor that caused sheep to congregate around these ponds was the placing of salt for grazing sheep close to these water sources (maps 1 and 2). As less reliable sources of water dried later in the grazing season, sheep were often trailed back to these large water sources even if they were only permitted to graze in the other unit of an allotment.

Domestic Sheep Use of Habitats

From 29 June to 14 October 1993 and 1994, detailed data concerning sheep bands and associated ecological factors were recorded on n = 32 (1993) and n = 34 (1994) sheep classification forms and a Global Positioning System waypoint was established for each location (maps 1-3). Both ecological and behavioral data were recorded regarding the sheep and the site where they were located. Site data including date, time, and Universal Transverse Mercator bearings were included with ecological measurements such as temperature, habitat type, slope, and aspect. Sheep behavior data included distances to elk, roads, sheep salting placements or natural mineral licks, and how many black sheep were present in the band. Sheep classification data were similar to that taken for elk, and vice versa, to document and analyze each species in the same manner. Differences in information collected dealt mainly with management practices for the sheep.

Features considered in sheep macrohabitat were measured to a standardized distance of less than or equal to 1,000 m. In relationship to the nearest macrohabitat feature (of less than or equal to 1,000 m), bands of sheep in 1993 were an average of 29.6 m (SD = 46.1) from a habitat edge, 177.8 m (SD = 169.2) from a ridgetop, 366.3 m (SD = 314.0) from water, 259.7 m (SD = 311.8) from a road, 234.9 m (SD = 316.4) from a sheep bed ground, 372.3 m (SD = 271.5) from a salting location or natural mineral lick, and 269.9 m (SD = 256.2) from human activity (appendix D, table D1). In 1994, and in relation to the nearest macrohabitat feature, classified sheep bands on the average were 38.8 m (SD = 50.3) from a habitat edge, 153.8 m (SD = 123.9) from a ridgetop, 520.8 m (SD = 273.4) from water, 321.3 m (SD = 248.1) from a road, 385.3 m (SD = 283.6) from a sheep bed ground, 465.6 m (SD = 274.5) from a salting location or natural mineral lick, and 535.7 m (SD = 287.2) from human activity (appendix D, table D1).

Because sheep production is tied to vehicular servicing, sheep and sheepherder servicing points were often by roads throughout the drainage (maps 1 and 2). A total of 96.9 percent of sheep locations in 1993, and 91.2 percent in 1994, were located less than or equal to 1,000 m from a road. By comparison, 88.9 percent of elk locations in 1993 and 71.7 percent of elk locations in 1994 were less than or equal to 1,000 m from a road (appendix D, table D1). Many salting sources throughout the drainage are near roads (mean = 411.1 m, SD = 48.7) (appendix D, table D2, and map 2). On the average, elk would be farther from roads if they did not frequent these salt placements for sheep.

In 1993, elevation at sheep band locations was only 30.4 m lower in fall (mean = 2,697.8 m, SD = 91.8) than in summer (mean = 2,728.2 m, SD = 100.5). In 1994, elevations were nearly the same in summer (mean = 2,717.2 m, SD = 95.6) and fall (mean = 2,718.2, SD = 112.2) (table 8). In fall and summer 1993 and 1994, sheep were always on slopes less than or equal to 26°. In summer 1993, sheep were 72.3 percent, and in 1994, 64.0 percent of the time, on north, northeast, east, and northwest aspects. In summer 1993, sheep were 27.9 percent, and in 1994, 36.0 percent of the time, on southeast, south, southwest, and west aspects. In fall 1993, sheep were 57.2 percent, and in 1994, 77.7 percent of the time, on north, northeast, east, and northwest aspects. In fall 1993, 42.9 percent, and in 1994, 22.2 percent of sheep locations were on southeast, south, southwest, and west aspects (table 8).

Sheep used 29.0 percent of 90 salting locations surveyed in 1993 and 1994 in or adjacent to the study area. The average distance of salt licks used by sheep to a ridgetop was 69.9 m (SD = 104.7), to a road was 229.0 m (SD = 329.7), and to a source of water was 349.8 m (SD = 406.5) (appendix D, table D2). These results demonstrate the effect of herding on sheep use of habitats. For example, sheepherders move the sheep to water in the day and to ridgetops with bed grounds. Sheep camps are generally next to roads, and often sheep are grazed in vicinity to these camps. In fall, sheep were found more often less than or equal to 1,000 m from human (mainly herding) activities (1993 = 92.9 percent; 1994 = 66.7 percent) than in summer (1993 = 33.3 percent; 1994 = 52.0 percent) (appendix D, table D1). More herding was required in fall because forage was depleted and sheep moved more often to search for adequate food supplies.

In summer 1994, 100 percent (mean = 87.0 m, SD = 114.6) of sheep were less than or equal to 600 m from mean elk horizontal obscurity cover. In fall 1994, 100.0 percent (mean = 127.6 m, SD = 100.0) of sheep bands were located less than or equal to 403 m (0.25 mile) from mean elk horizontal obscurity cover (appendix D, table D1). Those sheep locations less than or equal to 1,000 m from water differed in 1993 and 1994. On the average, sheep were 416.8 m (SD = 296.4) in summer 1993, 220.7 m (SD = 241.1) in fall 1993, 494.9 m (SD = 272.9) in summer 1994, and, 579.0 m (SD = 283.7) in fall 1994 from water (appendix D, table D1). On only one occasion (29 June 1994) were domestic sheep observed to be less than or equal to 1,000 m from elk and mule deer as a sheep band was classified. A herd of 19 elk were 405.0 m and three deer were 147.0 m from these sheep (appendix D, table D1).

Macro and Micro Factors, Use and Dietary Analyses of Elk and Sheep Feeding Sites

Sample Sizes of Feeding Sites and Vegetation Classes—In 1993, 43 (21 sheep and 22 elk) feeding sites were analyzed, and in 1994, 57 (24 sheep and 33 elk) feeding sites were analyzed. During the study, 188 vascular plant species representing 37 families (appendix D, table D3) were identified in the study area. Plant nomenclature follows that of Welsh and others (1993). Plant vouchers representing 160 species were initially verified by Dr. Kimball T. Harper of the Department of Botany and Range Science at Brigham Young University. A final verification was conducted by Dr. Duane Atwood of the Brigham Young University Herbarium at the Monte L. Bean Life Science Museum.

Introduced species accounted for 14 (7.4 percent) of all species, and 163 (86.7 percent) could be considered perennial species (appendix B, table B3). Of the 188 identified species in the study area 142—90 forbs, 22 grasses, 10 sedges, 19 woody species (shrubs and trees), and 1 rush—were subjected to previously described plant community composition and utilization analyses at elk and domestic sheep feeding sites (appendix A, tables A2 to A4). The number of plant species found differed between years. In 1993, 96 plant species—66 forbs, 12 grasses, 11 woody species (shrubs and trees), 6 sedges, and 1 rush—were found in the 43 feeding sites considered (appendix A, tables A2 to A4). By comparison, in 1994, 57 feeding sites were examined and 127 plant species—(81 forbs, 20 grasses, 18 woody species (shrubs and trees), 7 sedges, and 1 rush—were identified (appendix A, tables A2 to A4).

Forage Utilization—Percent use by elk and sheep of the respective plant life form classes (forbs, grasses, carices, rushes, and woody species) tended to increase through the seasons (table 12). For example, elk used at least a portion of the standing biomass of 44.2 percent of all plant species sampled in spring 1994; by summer 1994, Willow Creek elk and sheep had foraged on 63.1 percent of all species sampled in feeding sites; and by fall 1994, elk and sheep had foraged on 80.8 percent of the 52 plant species found in fall 1994 elk and sheep feeding sites. By comparison, Edge and others (1988) recorded elk use of 93 species—18 shrubs, 17 graminoids, and 58 forbs—at 121 feeding sites in 1982 and 1983, and found elk consumed 86 (early summer) and 76 (late summer) forage species.

In the study area, elk utilized an average of 4.9 percent (SD = 4.0) and sheep 12.9 percent (SD = 8.8) of the available dry herbage sampled in 1993, and in 1994, elk utilized an average of 4.8 percent (SD = 5.3) and sheep 9.0 percent (SD = 5.6) of the available dry herbage sampled (table 13). The 95 percent confidence intervals calculated for percent forage use give great confidence to results from utilization sampling because the means of all sampling scenarios lie in the calculated intervals. For example, percent use of dry standing herbaceous biomass at elk feeding sites in 1994 was (mean = 4.8, SD = 5.3). The 95 percent confidence interval for these data was 2.9 to 6.7 percent (table 13). These data suggest that one can be 95 percent confident that the true estimated percent use of dry herbage by elk at feeding sites sampled in 1994 was between 2.9 and 6.7 percent.

The highest percent utilization of dry herbage at an elk feeding site was 27.4 percent in unit 1 of the McKinney allotment in 1994 and was in an area previously grazed by sheep (table 14). Utilization values for elk in fall are an indication of dual use of the area because all elk feeding site locations in fall had been grazed previously by sheep. Thus, elk herbivory in fall was additive to previous summer and fall use by sheep or elk or both. This suggests that the combined use of standing herbaceous forage by elk and sheep may approach 30 percent in dually used areas.

The highest utilization at a sheep feeding site was 33.8 percent in unit 1 of the Davis allotment in 1993 (table 14). The lowest at a feeding site by elk was 0.3 percent in unit 3 of the Ingram allotment in 1994. By sheep at a feeding site, the lowest was 0.6 percent in unit 2 of the McKinney allotment in 1994 (table 14). Observers disturbed animals from some elk feeding sites in 1993 and 1994 and some sheep feeding sites in 1993 to the extent that the animals left the feeding site. Unpaired *t*-tests were conducted to determine if there were any differences between the percent of standing biomass consumed at these disturbed feeding sites and normal, undisturbed feeding sites. Results indicated that there were no significant differences ($P > 0.05$) in the use of standing biomass between disturbed and undisturbed sites. These data were thus considered normal and were included in all calculations.

Elk-to-Sheep Forage Use Ratios—Nichols (1957a,b) calculated ratios of elk-to-sheep use of dry forage production as

$$\frac{\textit{Sheep percent use of forage production}}{\textit{Elk percent use of forage production}}$$

on a nearly 162 ha (400 acre) mountain park at 3,355 m (11,000 feet) on the White River National Forest, CO. Nichols (1957a) calculated a ratio of elk-to-sheep use of total forage production (including browse) of 1:4.44 in 1955 and 1:3.79 in 1956. Comparatively, an elk-to-sheep use ratio of Willow Creek dry herbaceous biomass was 1:2.6 in 1993, and 1:1.9 in 1994 (table 13). By including browse in the average use of available dry standing biomass at feeding sites, elk in 1994 consumed an average of 4.0 percent (SD = 2.5) and sheep 6.7 percent (SD = 4.8) at feeding sites (table 14).

Table 12—Forb, grass, rush, sedge, and browse seasonal sample sizes and their individual and combined use by elk and domestic sheep, 1993 and 1994. All use values except 1993 browse values are based on those species where elk and domestic sheep or both had utilized a portion of the seasonal standing biomass. Use of browse in 1993 was determined by the percent of individual plants browsed. Mature and young browse classes in 1993 were combined to standardize use.

		Used		Elk only		Sheep only		Combined	
Plant types	**n**	**n**	**Percent**	**n**	**Percent**	**n**	**Percent**	**n**	**Percent**
1993 spring									
Forbs[a]	23	6	26.1	6	100.0				
Grasses	6	6	100.0	6	100.0				
Sedges	1	1	100.0	1	100.0				
Browse	1	1	100.0	1	100.0				
Total	31	14	45.2	14	100.0				
1993 summer									
Forbs[a]	68	43	63.2	10	23.3	20	46.5	13	30.2
Grasses	12	11	91.7	1	9.1	3	27.3	7	63.6
Rushes	1	0	0.0						
Sedges	6	4	66.7	0	0.0	3	75.0	1	25.0
Browse	7	6	85.7	2	33.3	1	16.7	6	50.0
Total	94	64	68.1	13	20.3	27	42.2	24	37.5
1993 fall[b]									
Forbs[a]	39	22	56.4	2	9.1	19	86.4	1	4.5
Grasses	9	8	88.9	0	0.0	5	62.5	3	37.5
Sedges	1	1	100.0	0	0.0	1	100.0	0	0.0
Browse	9	7	77.8	0	0.0	5	71.4	2	28.6
Total	58	38	65.5	2	5.3	30	78.9	6	15.8
1994 spring									
Forbs[a]	61	23	37.7	23	100.0				
Grasses	11	9	81.8	9	100.0				
Rushes	1	1	100.0	1	100.0				
Sedges	4	2	50.0	2	100.0				
Browse	9	3	33.3	3	100.0				
Total	86	38	44.2	38	100.0				
1994 summer									
Forbs[a]	66	37	56.1	4	10.8	19	51.4	14	37.8
Grasses	20	18	90.0	2	11.1	10	55.6	6	33.3
Rushes	1	0	0.0			0	0.0		
Sedges	6	6	100.0	0	0.0	5	83.3	1	16.7
Browse	18	9	50.0	1	11.1	5	55.6	3	33.3
Total	111	70	63.1	7	10.0	39	55.7	24	34.3
1994 fall[b]									
Forbs[a]	31	27	87.1	6	22.2	7	25.9	14	51.9
Grasses	9	6	66.7	0	0.0	2	33.3	4	66.7
Sedges	3	3	100.0	0	0.0	3	100.0	0	0.0
Browse	9	6	66.7	0	0.0	2	33.3	4	66.7
Total	52	42	80.8	6	14.3	14	33.3	22	52.4

[a] Woody plants with a basal stem diameter ≤0.32 cm were considered to be forbs due to their small size and forb-like texture.
[b] Species in fall elk feeding sites may have been previously utilized by sheep.

Table 13—Means and confidence intervals of percent use of dry biomass at feeding sites, 1993 and 1994. A forage use ratio of elk use to domestic sheep use is provided. The sum of elk and domestic sheep mean forage use are listed as a total and represent combined forage use. Use of dry browse biomass available to elk (0-1.83 m) and domestic sheep (0-1.53 m) is included with the use of dry herbaceous biomass in 1994.

	Mean	SD	SE[a]	df[a] (n-1)	CI (95 percent)	Elk : Sheep use ratio	Mean w/browse	SD	SE[a]	df[a] (n-1)	CI (95 percent)	Elk : Sheep use ratio w/browse
1993												
Elk	4.9	4.0	0.8	21	(3.1 to 6.6)							
Sheep	12.9	8.8	1.9	20	(8.9 to 16.9)							
Total	17.8					1:2.6						
1994												
Elk	4.8	5.3	0.9	32	(2.9 to 6.7)		4.0	2.5	0.4	32	(3.1 to 4.9)	
Sheep	9.0	5.6	1.1	23	(6.6 to 11.3)		6.7	4.8	1.0	23	(4.7 to 8.7)	
Total	13.8					1:1.9	10.7					1:1.7

[a] Standard error (SE) and degrees of freedom (df) were used to calculate the 95 percent confidence interval (CI). Otherwise, variance is expressed as the standard deviation (SD).

Table 14—Percents of available dry biomass utilized at elk and domestic sheep feeding sites, 1993 and 1994. Herbaceous vegetation utilization, 1993 and 1994. Utilization of herbaceous vegetation and percent of browse available to elk (0-1.83 m) and domestic sheep (0-1.53 m) in 1994.

	1993 elk		1993 sheep		1994 elk			1994 sheep		
Feed site[a]	Allotment and unit	Percent use	Allotment and unit	Percent use	Allotment and unit	Percent use	Percent use with browse	Allotment and unit	Percent use	Percent use with browse
1	Road Hollow 2	2.2	McKinney 2	15.6	Center Canyon 1	3.3	3.3	McKinney 1	2.9	2.9
2	McKinney 1	10.0	McKinney 1	3.3	McKinney 1	6.8	6.8	McKinney 2	0.6	2.5
3	McKinney 1	6.5	Davis 1	12.5	McKinney 1	1.7	1.7	McKinney 1	5.9[b]	5.9[b]
4	Davis 1	2.1	Broad Hollow 5	1.2	Center Canyon 1	4.7	4.8	Road Hollow 1	10.9	2.7
5	Davis 1	4.7	Davis 2	8.8	Center Canyon 1	5.0	5.0	Cabin Springs 1	3.6	0.9
6	McKinney 1	1.2	Center Canyon 2	31.6	McKinney 1	1.9	1.9	Center Canyon 1	1.0	3.3
7	McKinney 1	4.5	Center Canyon 2	10.9	McKinney 1	5.3	5.3	Beaver Creek 4	4.8[b]	4.8[b]
8	Center Canyon 1	5.1	Cabin Springs 1	11.4	Davis 1	1.6	1.6	Davis 1	14.0[b]	13.8[b]
9	Cabin Springs 2	3.3	Davis 1	5.6	McKinney 1	1.0	1.0	Center Canyon 2	12.1	10.7
10	Cabin Springs 2	1.3	Davis 1	8.5	McKinney 1	2.3	2.3	McKinney 1	18.8[b,c]	6.9[b,c]
11	Cabin Springs 2	2.5	Cabin Springs 2	4.4	McKinney 1	3.9	3.9	Ingram 3	3.2	2.0
12	McKinney 1	8.2	Road Hollow 1	16.5	Center Canyon 1	5.5	5.5	Davis 1	12.2[b]	12.2[b]
13	Cabin Springs 1	0.8	Center Canyon 2	4.2	Center Canyon 1	5.0	5.0	Beaver Creek 1	16.4	16.4
14	Davis 1	1.4	McKinney 2	4.0	McKinney 1	6.4	6.4	Cabin Springs 2	11.1	9.3
15	Davis 2	6.7	McKinney 1	22.3	McKinney 1	1.0	1.0	Road Hollow 2	3.7	3.0
16	Davis 2	6.9	Beaver Creek 4	20.7	McKinney 1	7.8	7.8	Davis 2	6.0[c]	3.9[c]
17	Davis 2	18.0[b]	Center Canyon 2	19.2	McKinney 1	6.5	6.5	Davis 2	6.2	6.2
18	McKinney 1	6.9	Davis 1	33.8	McKinney 1	5.7	5.8	Ingram 3	12.6[c]	14.1[c]
19	Center Canyon 1	6.9	Davis 2	12.9	McKinney 1	0.6	0.6	Cabin Springs 2	13.2	1.8
20	Center Canyon 1	1.8	Road Hollow 2	12.0	Cabin Springs 1	1.2	1.2	Center Canyon 2	8.1	4.6
21	Center Canyon 1	4.5	Road Hollow 1	11.9	Cabin Springs 1	2.6	3.1	Davis 1	11.6	12.7
22	McKinney 2	1.2[b]			Center Canyon 1	6.6[c]	8.7[c]	Center Canyon 1	5.3[b]	2.4[b]
23					McKinney 1	2.1	2.2	Cabin Springs 1	9.7	13.2
24					Center Canyon 1	4.9	5.2	Davis 2	21.3[b]	5.4[b]
25					Road Hollow 1	4.8	3.0			
26					Ingram 3	2.1	1.4			
27					Ingram 3	0.3	0.7			
28					McKinney 2	1.0	2.4			
29					McKinney 1	7.3[c]	7.6[c]			
30					Center Canyon 2	2.2	2.9			
31					McKinney 1	2.0[c]	2.0[c]			
32					Center Canyon 2	18.3[b]	8.9[b]			
33					McKinney 1	27.4[b]	7.4[b]			
Min		0.8		1.2		0.3	0.6		0.6	0.9
Max		18.0[b]		33.8		27.4[b]	8.9[b]		21.3	16.4

[a] Spring elk feeding sites were 1-4 (1993) and 1-20 (1994). Summer elk feeding sites were 5-21 (1993) and 21-31 (1994). Fall elk feeding sites were 22 (1993) and 32 and 33 (1994). Summer sheep feeding sites were 1-14 (1993) and 1-20 (1994). Fall sheep feeding sites were 15-21 (1993) and 21- 24 (1994).

[b] Feeding sites where sheep had previously grazed.

[c] Feeding sites where elk had previously grazed.

These utilization means, including browse, resulted in a ratio of elk-to-sheep utilization of available dry standing biomass at feeding sites of 1:1.7, or sheep consumed 1.7 times as much forage as elk in the study area, in 1994 (table 13).

Pickford and Reid (1943) reported that elk consumed 216.6 kg per ha (193.2 lb per acre) of the total forage produced (including browse) in 1940 and sheep consumed 344.1 kg per ha (307.0 lb per acre) in 1937 of the total forage (including browse) produced on a 307.4 ha (759 acre) meadow on the headwaters of the John Day River in the Whitman National Forest, OR. Converting values from Pickford and Reid's study, a ratio of elk-to-sheep use of forage produced (including browse) in different years (sheep in 1937; elk in 1940) is 1:1.6. This last elk-to-sheep forage use ratio of all biomass including browse calculated from Pickford and Reid is close to the Willow Creek elk and domestic sheep average forage use ratio of 1:1.7, which includes browse in 1994 (table 13).

Utilization of Individual Plants—Counting the individuals of a plant species fed on by elk or sheep was a second method used to measure utilization. These data were expressed as a percent of the individuals present. In conjunction with other measurements of vegetation, these data reflect foraging patterns, intensity, and preference for plant species by elk and sheep. For example, in 1993 Kentucky bluegrass (*Poa pratensis*) individuals were used by elk an average of 10.7 percent in spring, 7.4 percent in summer, and 14.0 percent in fall. Sheep used an average of 12.2 percent and 25.0 percent in summer and fall, (appendix A, table A2). Kentucky bluegrass was found commonly in 1993 on elk and sheep feeding sites (Beck 1996). More individual plants were used as the 1993 season progressed.

Ivlev's electivity index of 1993 elk and sheep diet preferences revealed that elk preference for Kentucky bluegrass, in relation to all other herbaceous plant species at feeding sites, increased from –0.79 in spring, to –0.37 in summer, to +0.06 in fall. Comparatively, sheep preference for Kentucky bluegrass in relation to all other herbaceous plant species at feeding sites, increased from –0.61 in summer to –0.34 in fall, 1993 (appendix A, table A5). These use values indicate that both elk and sheep exhibited a trend for higher preference of Kentucky bluegrass as the seasons progressed to fall in relation to other seasonally available species.

Elk and Domestic Sheep Seasonal Diets—Based on the percent relative dry weight of plants in diets, and by grouping grasses, sedges, and rushes as graminoids, the herbaceous diets of elk were nearly the same in 1993 and 1994. The difference between the 1993 and 1994 sheep herbaceous (woody plants not included) diet was due to 23.1 percent more of the diet being comprised of graminoids in 1994 than in 1993 (fig. 10). Forbs in 1994 were not as important to sheep as they were to elk, and their amount decreased 8.8 percent from summer to fall to being 8.5 percent of fall sheep diets (fig. 11). Graminoids were 58.6 percent of sheep summer diets in 1994 (fig. 11) with 11.3 percent of this total attributed to sedges. By fall 1994, graminoids constituted 37.8 percent of the overall sheep diet (fig. 11); 6.6 percent of this was sedge biomass. Sedges made up a high of 14.3 percent of the diets of elk in spring 1993 and of 23.0 percent of fall sheep diets in 1994. Sedges were a more substantial

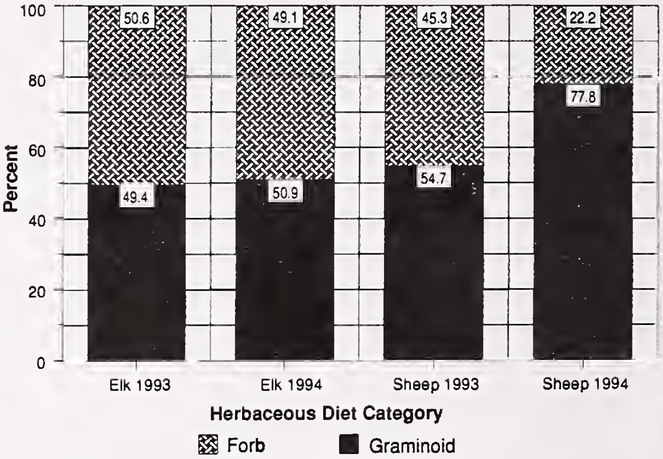


Figure 10—Percent relative dry weight of graminoids and forbs in the herbaceous diets of elk and domestic sheep, 1993 and 1994.

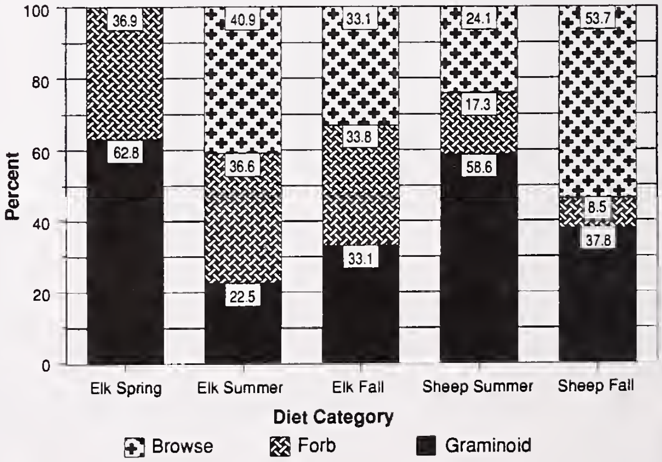


Figure 11—Percent relative dry weight of graminoids, forbs, and browse in seasonal elk and domestic sheep diets, 1994. Browse comprised 0.3 percent of elk diets in spring, 1994.

part of sheep diets than elk diets (appendix A, tables A1, A2, and A4). Rushes (usually called wiregrass by stock producers) made up only 0.6 percent of elk diets in spring 1994, and this was the only instance when rushes were incorporated into the diets of elk. Rushes were never eaten by sheep (appendix A, tables A1 and A4).

In 1994, browse was a minor portion (0.3 percent) of the elk diet in spring and a substantial part of the summer (40.9 percent) and fall elk diets (33.1 percent). Consequently, the browse component in elk diets was certainly insignificant in spring 1994 (fig. 11). In 1994, the diets of sheep consisted of 24.1 percent browse in summer, and by fall, sheep diets contained 53.7 percent browse (fig. 11). Accordingly, as browse became increasingly important to sheep in fall and remained a substantial portion of elk fall diets, the combined use by elk and sheep of the number of woody species sampled increased from 33.3 percent in summer 1994 to 66.7 percent in fall 1994 (table 12).

Forbs were a relatively constant part of the elk seasonal diet in 1994, and graminoids were most important to elk diets in spring (62.8 percent; 3.0 percent sedges and rushes). Graminoid intake decreased in summer and increased by 10.6 percent from summer to fall to constitute 33.1 percent of the fall elk diet (fig. 11). According to Nelson and Leege (1982:354) "Almost all researchers agree that grass is the most important forage class for elk during spring green-up months, usually constituting 85 percent of the diet. An exception occurs when deep snow conditions extend into spring and limit elk use of grass." The herbaceous diets of elk in spring included 25.1 percent grasses in 1993 and 59.8 percent in 1994. The difference in spring graminoid use by elk between years can be attributed to the large, persistent snowpack in 1993, which precluded elk from concentrating foraging activities on graminoids. Elk concentrations occurred later in the season when forbs were more dominant in the forage base.

Using fecal nitrogen content as an index of diet quality, Hanley (1980) reported that graminoids and forbs in the Cascade Mountains in Washington were the best forage sources for elk, but the relative quality of graminoids decreased from being the highest quality forage from May to June to being the second lowest quality forage resource (second only to shrub stems) from September to October. Fecal nitrogen contents in elk diet composition showed a continued reliance on forbs throughout the study period and a gradual shift away from graminoids and toward shrubs as the season progressed (Hanley 1980). Comparatively, results in figure 11 indicate a similar trend in elk seasonal diets.

By grouping grasses and grasslike vegetation into one category, Nichols (1957a) determined that grasses and grasslike species were 57.82 percent of elk diets and 47.30 percent of sheep diets in his study of elk and domestic sheep vegetative utilization in northwestern Colorado. Nichols reported that elk incorporated 41.3 percent forbs and sheep 49.5 percent forbs into their diets. Browse in this study was only 0.88 percent of elk diets and 3.16 percent of sheep diets. In Willow Creek, combined spring, summer, and fall 1994, elk diets consisted of 36.1 percent forbs, 37.4 percent graminoids, and 26.5 percent browse. In 1994, the combined summer and fall diets of sheep comprised 15.7 percent forbs, 54.8 percent graminoids, and 29.5 percent browse. Comparatively, Willow Creek elk diets were comprised of more forbs and browse and fewer graminoids, and Willow Creek sheep diets were composed of more graminoids and browse and less forb herbage than elk and sheep in the Nichols' study.

Elk and Domestic Sheep Dietary Similarity—Kulcynski's similarity (Oosting 1956) indices (similarity values of zero indicate that only one herbivore used a given plant species) demonstrate a percent of dietary overlap of elk and sheep use of plant species. The relative proportions of plants in elk and sheep diets reveal much about commonalities in use and diets of elk and sheep for forage species (appendix A, tables A3 and A4). The highest percent similarity regarding the use of standing biomass was 99.9 percent for Fremont goosefoot (*Chenopodium fremontii*) in summer 1993. Elk used 4.27 percent and sheep 4.26 percent of the standing biomass of this annual forb during this period (appendix A, table A3). This species was not a significant (more than or equal to 90 percent) portion of elk or sheep diets in summer 1993 (appendix A, table A4) and was only 0.16 percent of elk and 0.10 percent of sheep diets during this time (similarity = 76.9 percent) (appendix A, table A4). This illustrates that similarity in use of standing biomass only indicates similar preference in relation to availability.

Species important in elk and sheep diets such as tall bluebell, mountain brome, and mountain snowberry reflected commonalities in diet preference resulting in high to moderate similarities (appendix A, table A4). For example, the diet similarity for tall bluebell was 75.0 percent between elk and sheep in summer 1993 and 47.6 percent in summer 1994 (appendix A, table A4). The proportion of tall bluebell in elk diets in summer 1993 was 40.45 percent, and tall bluebell was 24.26 percent of sheep diets at that time. By comparison, in summer 1994, this forb was 20.37 percent of elk ingesta and was 6.37 percent of sheep diets (appendix A, table A4). To elk, tall bluebell was the most important forb species in spring, composing 56.29 percent of the 1993, elk spring diet and elk used 12.67 percent of the standing biomass; in spring 1994, elk diets consisted of 26.52 percent tall bluebell, and elk used 8.50 percent of standing tall bluebell biomass (appendix A, table A1).

Between 1959 and 1964, Matthews (1965) found that tall bluebell had been used by sheep an average of 7 percent by late spring (15 to 22 June), and 25 percent in summer (6 to 23 August) in unit 2 of the Mud Creek sheep allotment in Strawberry Valley. Matthews also found that cattle had used an average of 46 percent in 1963 and 38 percent in 1964 of tall bluebell between the first and middle of July in the adjacent Clyde Creek Cattle allotment. In Willow Creek, once mildew contaminated tall bluebells, utilization quickly diminished, although some tall bluebell was fed on in the fall (appendix A, tables A2 to A4). Powdery mildew (*Erysiphe cichoracerarum*) infection of tall bluebell does not appear to cause initial drying or lodging of stems but may hasten the drying of foliage once soil moisture conditions promote this process (Matthews 1965). In Mud Creek, mildew infection reportedly began on 6 August, generally reaching maximum infection rates by 18 August.

Elk and Domestic Sheep Dietary Overlap—Olsen and Hansen (1977) compared the average dietary similarity of elk, domestic sheep, pronghorn, cattle, and wild free-roaming horses in the Red Desert of southwestern Wyoming. They included Spearman's rank correlation coefficient (r_s) values of dietary overlap as a comparison to the dietary similarity values. Spearman's rank correlation coefficient (r_s) measures the monotonic association between two variables y and x (for example, y = relative percent dry biomass in seasonal elk diets; and x = relative percent dry biomass in seasonal sheep diets) (Ott 1993). That is, the rank correlation coefficient (values range from –1.0 to +1.0) measures whether y (relative percent dry biomass in seasonal elk diets) increases or decreases with x (relative percent dry biomass in seasonal sheep diets), even when the relation between y and x is not necessarily linear (Ott 1993). Seasonal relative percent of dry biomass by species in elk and sheep diets (appendix A, table A4) were ranked and subjected to Spearman's correlation tests (Minitab 1993; Ott 1993). These results were compared to the mean similarity of relative percent of dry biomass in elk and sheep diets (table 15).

Overall mean similarity of elk and sheep diets varied within the plant life form classes (forbs, graminoids, and browse) and between seasons. For example, the mean similarity of the relative percent of dry graminoid biomass in elk and sheep diets in fall 1994 was 29.7 ± 38.6 percent. However, r_s was –0.10 ($P = 0.842$), indicating that sheep use of graminoids did not increase at the same time as the use by elk increased (table 15). By comparison, in summer 1994, mean similarity based on the relative percent of graminoids in diets was 32.0 ±

Table 15—Seasonal dietary overlap of elk and domestic sheep. Based on similarities of the seasonal relative percent of dry biomass in diets, 1993 and 1994. Overlap represented through means and Spearman's rank correlation coefficients (r_s). Browse in 1994 only.

		Percent similarity		Spearman's	
	n[a]	Mean	SD	r_s	P[b]
1993 summer					
Forbs	27	22.3	31.0	0.25	0.194
Graminoids	8	65.8	27.8	0.71	0.059
Total diet	35	32.3	35.2	0.55	0.001
1993 fall					
Forbs	2	13.5	19.1	–1.00	0.000
Graminoids	5	10.4	10.1	0.21	0.682
Total diet	7	11.3	11.5	0.26	0.525
1994 summer					
Forbs	23	33.3	33.1	0.60	0.005
Graminoids	9	32.0	31.7	0.18	0.604
Browse	4	64.6	25.3	0.80	0.166
Total diet	36	36.4	32.8	0.63	0.000
1994 fall					
Forbs	6	30.4	34.1	0.75	0.092
Graminoids	5	29.7	38.6	–0.10	0.842
Browse	4	69.3	31.3	–0.20	0.729
Total diet	15	40.5	37.1	0.53	0.046

[a] The number of species in each forage class used by both elk and sheep.
[b] Significant correlations ($P < 0.05$).

31.7 percent, with $r_s = 0.18$ ($P = 0.604$), demonstrating that sheep use of graminoids did increase to some extent as elk use of graminoids increased, and vice versa.

The highest correlation coefficient on the percent relative use of a forage class was $r_s = 0.80$ ($P = 0.166$) for woody plants in summer 1994 with a mean similarity of 64.6 ± 25.3 percent. During summer 1994, aspen and mountain snowberry were 10.2 percent and 13.4 percent of elk and 3.0 percent and 11.3 percent of sheep diets. These two woody species were included in the suite of species constituting more than or equal to 90 percent of elk and sheep diets (appendix A, table A4).

Overall total mean diet similarity in summer 1993 was 32.3 ± 35.2 percent, and $r_s = 0.55$ ($P = 0.001$), and in summer 1994 was 36.4 ± 32.8 percent and $r_s = 0.63$ ($P = 0.000$). All seasonal dietary similarities were significant ($P < 0.05$) except in fall 1993 (table 15). The summer values give the best indication of elk and sheep dietary similarities because there were larger sample sizes to compare and sheep had not previously grazed at all elk feeding sites as was the case in all fall elk feeding sites (table 14). Overall total diet overlap values in summer 1994 are the best values used because they included woody plants. It appears then, that the best calculations of elk and domestic sheep dietary overlap in the Willow Creek drainage approach 37 percent.

Olsen and Hansen (1977) reported an average similarity of elk and domestic sheep seasonal dietary overlap of 30 ± 15 percent, $r_s = 0.61$. Only horses and cattle had a higher Spearman's rank correlation coefficient ($r_s = 0.64$), which seems plausible because graminoids were the dominant fraction of cattle and horse diets in this forb-limited study area (Olsen and Hansen 1977). Using Kulczynski's similarity index, MacCracken and Hansen (1981) found elk diets overlapped sheep diets 46 ± 11 percent on south-central Colorado big game winter range.

Comparing other research on sheep diets in aspen habitat, MacCracken and Hansen (1981) concluded that grasses and grasslike plants made up a higher percentage of sheep diets in their study area than forbs because forbs did not make up as large of a proportion of the relative biomass in their study area as they would in an aspen type. Thus, it appears that sheep use of forbs is a matter of availability. Use of forbs by elk as also related to availability is seen in Pickford and Reid's (1943) study of elk and domestic sheep forage utilization in eastern Oregon. Forb herbage formed more than 80 percent of the elk diet as compared with 66 percent for sheep. Pickford and Reid felt the preponderance of forbs in the summer diet of these elk was reflected in the composition of the vegetation: 76 percent forbs, 14 percent grasses, sedges, and rushes, and 10 percent shrubs. Variation in the vegetative complement within and between each plant community should likewise be factors influencing elk and sheep dietary similarities.

Spearman's rank correlations were calculated for seasonal diet similarities between seasons and between the ungulate species in question. These data reveal that in 1994 (the year when the proportion of browse in diets was determined) diets of elk and sheep correlated significantly in all seasons intraspecifically and interspecifically, except for the diets of elk in spring and fall ($r_s = 0.26, P = 0.276$) and the diets of elk in fall and sheep in summer ($r_s = 0.40, P = 0.069$) (table 16). These data support the visual display of seasonal elk and sheep diets in 1994 in figure 11. By comparison, elk diets in spring 1994 contained virtually no browse and were composed chiefly of graminoids, while elk diets in fall 1994 consisted of nearly equal amounts of forbs, graminoids, and browse. Comparatively, figure 11 shows the nonsignificant correlation of fall elk diets with that of summer sheep diets in 1994 where sheep diets were dominated by graminoids (58 percent) in summer 1994 and elk diets in fall 1994 consisted of nearly equal amounts of forbs, graminoids, and browse.

Seasonal herbaceous diets of elk and sheep were correlated intraspecifically between 1993 and 1994. These correlations indicate that elk spring, and sheep summer and fall, nonwoody foods were significantly correlated ($P < 0.05$) in 1993 and 1994. The herbaceous diets of elk in summer and fall did not correlate significantly ($P > 0.05$) between the 2 years (table 16). A possible explanation as to why these diets differed may be attributed to a difference in forage conditions. Although herbaceous diets of elk in both 1993 and 1994 consisted of a nearly 1-to-1 ratio of graminoids and forbs (fig. 10), elk seasonally adjusted their diets (fig. 11). The ability to select forage differentially can be related to forage abundance. Standing biomass data indicate that forb production was greatly diminished and was essentially subsidized in 1994 by graminoids (appendix C, table C2). The main speculative difference for this was the decrease in snowpack on the magnitude of 2.4 from 1993 to 1994. Due to a decrease in moisture, forbs in 1994 were not as abundant as in 1993, and as a result, elk may have switched from eating forbs to eating browse in summer and fall 1994. Because there are no data to verify browse consumption by elk or sheep in 1993, these comparisons are speculative but seem plausible.

Elk and Domestic Sheep Animal Unit Equivalents—An animal unit (AU) is "a 454-kg (1,000 lb), nonlactating cow or its equivalent in animal demand or potential forage intake" (Vallentine 1990:457). According to Flinders (1988:48): "The AU concept is used to account for units of forage use on rangeland and is the basis for determining carrying capacity and stocking rates." An animal unit month (AUM) is the amount

Table 16—Spearman's rank correlation coefficients (r_s) of the relative percent of dry biomass in elk and domestic sheep diets on a seasonal basis, 1993 and 1994. Browse in 1994 only. A comparison of the herbaceous diets of elk and domestic sheep on a seasonal basis between 1993 and 1994 is included.

	Elk Spring	Elk Summer	Elk Fall	Sheep Summer	Sheep Fall
1993 (herbaceous diets only)					
Elk—Spring					
P					
Elk—Summer	0.59				
P	0.008				
Elk—Fall	–0.09	0.46			
P	0.824[a]	0.194[a]			
Sheep—Summer	0.80	0.55	0.32		
P	0.000	0.001	0.362[a]		
Sheep—Fall	0.71	0.71	0.26	0.73	
P	0.007	0.001	0.525[a]	0.000	
1994 (herbaceous diets with browse diets)					
Elk—Spring					
P					
Elk—Summer	0.52				
P	0.003				
Elk—Fall	0.26	0.50			
P	0.276[a]	0.029			
Sheep—Summer	0.59	0.63	0.40		
P	0.000	0.000	0.069[a]		
Sheep—Fall	0.41	0.52	0.53	0.78	
P	0.047	0.020	0.046	0.000	
1993 versus 1994 (herbaceous diets only)					
Elk—Spring	0.66				
P	0.003				
Elk—Summer		0.29			
P		0.134[a]			
Elk—Fall			0.77		
P			0.085[a]		
Sheep—Summer				0.63	
P				0.000	
Sheep—Fall					0.65
P					0.009

[a] Indicates nonsignificant diet correlations ($P > 0.05$).

of dry forage required to feed one AU for 30 days (1 month). This amount is generally considered to be 340.5 kg (750 lb) (Vallentine 1990). In the classical sense, an animal unit equivalent (AUE) is a quantitative expression of forage demand of a particular kind and class of herbivore relative to an animal unit (Vallentine 1990). Animal unit equivalents are often used to relate forage intake of different ungulate species based on a ratio of metabolic liveweight (MBW). A flaw occurs in these standard animal unit equivalent calculations because there is no accounting for dietary or habitat use overlap in interspecific calculations (Flinders 1988; Vallentine 1990).

In light of the above criteria and arguments, animal unit equivalents for elk and domestic sheep in 1993 and 1994 were computed seasonally by the standard method and also by a method developed by Flinders (1988) that calculates animal unit equivalents with the percent of dietary overlap. Both animal unit equivalent calculations were based on metabolic liveweights of elk and sheep. In the study area, an average adult elk weighed 216.1 kg (476.5 lb), and an average adult sheep (ewe) weighed 67.2 kg (148.2 lb) (table 17). The standard animal unit equivalent based solely on metabolic liveweight was 2.4 sheep to 1 elk (table 17). Or 2.4 average-sized ewes were required to consume the same amount of food as one average-sized elk in the study area.

Table 17—A comparison of seasonal standard animal unit equivalents (AUE's) and AUE's calculated on dietary overlap of elk and domestic sheep in the Willow Creek study area. Browse calculated into 1994 diets only.

	Mean elk weight (kg)[a]	Mean sheep weight (kg)[b]	Standard AUE[c] sheep:1 elk	Mean percent dietary overlap[d]	Dietary method AUE[e] 1 elk:sheep
Summer 1993	216.1	67.2	2.4	32.3	1:7.4
Fall 1993	216.1	67.2	2.4	11.3	1:21.2
Summer 1994	216.1	67.2	2.4	36.4	1:6.6
Fall 1994	216.1	67.2	2.4	40.5	1:5.9

[a] Mean weights of live elk by age categories from Hornocker (1970) and calculated with sex and age ratios of 163 mature elk classified on June 23, 1994, at 9:00 a.m.

[b] Mean weights of live sheep calculated by weight estimates of ewes provided by H. Wilson (1995, personal communication) and E. Butterfield (1995, personal communication).

[c] These values computed as a ratio of elk to sheep metabolic live weight (MBW [elk weight (kg)$^{0.75}$/sheep weight (kg)$^{0.75}$]).

[d] These data from table 15.

[e] These values computed as a ratio of elk to sheep metabolic live weight (MBW) divided by the percent of dietary overlap ([elk weight (kg)$^{0.75}$/sheep weight (kg)$^{0.75}$]/ percent dietary overlap).

Vastly different results were acquired by figuring the percent of seasonal dietary overlap into animal unit equivalent calculations. Animal unit equivalents calculated by this dietary method ranged from a low of 5.9 sheep per 1 elk in fall 1994 to 21.2 sheep per 1 elk in fall 1993 (table 17). Little confidence can be applied to the fall 1993 animal unit equivalents value owing to a low sample size of elk feeding sites (n = 1). Due to a large sample size and the inclusion of browse, the most predictive value of elk and sheep equivalents was in summer 1994. This value indicated that it required 6.6 average-weight ewes to eat the same amount of dry forage of the same plant species composition as one average-weight elk in the Willow Creek study area (table 17). This last method of animal unit equivalent calculations, which incorporates dietary overlap, gives the best indication of how much forage of the same species composition a single elk ingests in comparison to numbers of sheep in the area.

Consumption of Forage in Animal Unit Months by Elk and Domestic Sheep—Animal unit month calculations were performed to ascertain how much forage was consumed by the yearly estimated population of adult elk and sheep in the study area. Juvenile elk and sheep were excluded in these calculations because no clear understanding existed as to how much of their diets were composed of milk or vegetation or both. Daily intake rates (kg) based on elk and sheep metabolic liveweight indicate that a 216.1-kg elk ate 2.5 kg (5.5 lb) and a 67.2-kg ewe ingested 1.1 kg (2.4 lb) of dry feed per day (table 18). The number of animal unit months consumed by adult elk was 485 in 1993 and 473 in 1994. Numbers of animal unit months eaten by adult sheep were 2,973 in 1993 and 2,842 in 1994. Slight decreases in animal unit months consumed from 1993 to 1994 were due to decreases in elk and sheep populations (table 18).

Nutritional Analyses of Plants Composing at Least 90 Percent of Seasonal Diets—Selected nutritional analyses according to the Association of Official Analytical Chemists (AOAC 1995) methods were performed on those plant species that composed at least 90 percent of seasonal elk and sheep diets (appendix B, table B1). The percent water content for all plant species (with a clipped wet weight greater than 0.5 g) was also determined (appendix B, table B2). Nelson and Leege (1982) indicated that biologists who work with elk generally use established protein standards for deer. French and others (1955, in Nelson and Leege 1982:332) "reported that 6 to 7 percent [crude protein] was needed in the diet for white-tailed deer maintenance, and 13 to 16 percent was required for growth." Nelson and Leege (1982) reported that a 260 kg (573.2 lb) cow elk would need about 20 percent more protein than required for maintenance during peak lactation. According to the National Research Council (1985), the crude protein maintenance requirement for ewes is 9.4 percent, and the crude protein requirement for ewes during the first 6 to 8 weeks of lactation while suckling singles (or the last 4 to 6 weeks of lactation while suckling twins) is 13.4 percent, which is an increase of 29.9 percent over the maintenance requirement.

The total energy readily available to a plant (and thus to herbivores upon ingestion) is determined by total nonstructural carbohydrate analyses (daSilveira and others 1978). The total nonstructural carbohydrate fraction thus includes those carbohydrates available without digestive breakdown of cellulose. Acid detergent fiber tests the "fraction of a feedstuff analyzed by the Van Soest scheme of detergent analysis used to divide carbohydrates in plant constituents into those highly available and poorly available to animals; [acid detergent fiber] content of a feed reflects the

Table 18—Forage consumption in terms of animal unit months (AUM's) by elk and domestic sheep in and adjacent to the Willow Creek study area, 1993 and 1994. Browse calculated into 1994 diets only.

	Mean weight (kg)[a]	Daily forage intake (kg)[b]	Days on range[c]	Population[d]	Total forage intake (kg)	AUM's
Elk 1993	216.1	2.5	168	393	165,060	485
Sheep 1993	67.2	1.1	107	8,600	1,012,220	2,973
Elk 1994	216.1	2.5	168	383	160,860	473
Sheep 1994	67.2	1.1	107	8,220	967,494	2,842

[a] Mean weights of live elk by age categories from Hornocker (1970) and calculated with sex and age ratios of 163 mature elk classified on June 23, 1994, at 9:00 p.m. Mean weights of live sheep calculated by weight estimates of ewes provided by H. Wilson and E. Butterfield (1995, personal communication). These data found in table 17.

[b] Daily forage intake = 0.045 x (Animal weight in kg)$^{0.75}$ (Giles 1978).

[c] Elk were considered to be on the range from 1 May to 15 October (168 days). Sheep were considered to be on the range from 1 July to 15 October (107 days).

[d] Elk populations were calculated from Utah Division of Wildlife Resources aerial censusing. Due to their relatively smaller size to mature elk, calf elk were probably misrepresented in these samples. This follows the calculation of mean elk size (only adult animals were considered) which coincides with the decision to not include lambs in the calculation of mean sheep weight. Sheep populations were calculated from sheep numbers reported to be authorized to graze in the allotments in 1993 and 1994 (S. Smith, 1993 and 1994, personal communication). Sheep numbers only account for adult ewes. Although sheep in the Beaver Creek, Ingram, and Pete's Knoll/Broad Hollow allotments grazed in the study area only part of the season, they grazed in adjacent units of their respective allotments for the remainder of the grazing season. No adjustments were made when considering elk densities due to the fact that collared elk cows inhabited additional areas adjoining the Willow Creek study area.

amounts of carbohydrates not solubilized by acid detergent" (Church and Pond 1988:445). Thus, plants with higher levels of acid detergent fiber contain more nondigestible material, such as cellulose and lignin.

From spring to summer, percent crude protein and total nonstructural carbohydrates (sugars) normally decreased, and percent acid detergent fiber tended to increase. For example, in spring 1994, crude protein in tall bluebell was 16.9 percent, total nonstructural carbohydrates were 15.7 percent and acid detergent fiber was 21.0 percent. By summer 1994, tall bluebell crude protein had dropped to 4.0 percent, total nonstructural carbohydrates had risen to 19.7 percent, and acid detergent fiber levels had risen to 38.1 percent. And, in fall 1994, crude protein levels in tall bluebell had risen to 6.3 percent, the levels of available nonstructural carbohydrates had dropped to 7.0 percent, and the amount of nondigestible carbohydrates was 27.8 percent (appendix B, table B1). Due to fall regrowth (seen in tall bluebell in 1994 and often in grasses) (Vallentine 1990), often a slight increase occurred from summer to fall in the percent of crude protein and total nonstructural carbohydrates, and at times a slight decrease in nondigestible carbohydrates was seen (appendix B, table B1). Seasonal fluctuations in tall bluebell contents of crude protein, acid detergent fiber, and total nonstructural carbohydrate different from expected trends probably reflected differences in microhabitat selection by elk and possibly sheep. Percent water content also decreased as the seasons progressed (appendix B, table B2). For example, mean water content of smooth brome in 1993 sheep feeding sites was 70.8 percent in summer and decreased to 44.9 percent in fall (appendix B, table B2).

Basing diet quality on fecal nitrogen content Hanley (1980) found that Columbian black-tailed deer and elk, in August and September on the west slope of the Cascade Mountains in Washington, shifted their foraging emphasis from searching for individual plants or habitat patches to microhabitats where plant phenology was delayed relative to average conditions. Elk in this study selected mesic habitat patches (24.6 percent of the study area and dominated by a graminoid and forb understory) significantly greater than their occurrence. In addition, Geist (1982) suggested that elk would opportunistically move seasonally to those areas where forage conditions were superior.

In relation to the nutritional impact of elk grazing in dry versus wet meadows before summer livestock entry, Mantz (1993) presented evidence that spring elk, grazing in the Uinta Mountains in the Wasatch National Forest of northeastern Utah, significantly reduced the crude protein content of mid-season standing forage in dry meadows but had no impact on the crude protein content of forage in wet meadows. The Willow Creek study has no data that indicate lower protein values in summer and fall forage in the study area resulting from spring elk grazing.

Generally in the fall, Willow Creek elk seemed to select areas far from roads where microhabitats advantageous to late season "green pockets" of vegetation due to slope exposure and tree cover (Hanley 1980) existed to take advantage of retarded plant phenology (table 8, maps 1 through 3, and appendix C, table C1). By seasonally following the phenology of individual plant species at elk feeding sites, it can be demonstrated that plants did not mature as quickly as might be expected (Beck 1996). In fall, elk used north, northeast, east, and northwest aspects more often than their availability (table 8). Thus, these data suggest that elk were using those areas that supplied the best forage per amount of time spent (in other words, farthest from human interference and roads, close to cover, and on aspects where plant phenology was slowed resulting in quality plant nutrition) (maps 1 through 3, appendix D, table D1, and table 8).

Elk and Domestic Sheep Forage Preferences—Electivity indices (Ivlev 1961), calculated by feeding site and averaged by plant species per season, indicate either avoidance (values 0.00 to –1.00) or preference (values 0.00 to +1.00) in relation to all other plant species analyzed based on a ratio of dry biomass in elk and sheep diets relative to the amount of dry biomass occurring in the environments sampled during the specified month. Only the value –1.00 represents nonuse. Avoidance values indicate that the relative proportion of ingested dry biomass of a given species in relation to total dry biomass available in the environment becomes less as the value approaches –1.00. Positive preference values have the inverse meaning of avoidance values and indicate some selectivity by the forager. These values thus help clarify seasonal forage preferences of elk and sheep in relation to availability of forage.

For example, in 1994, the amount of dry biomass of a forb, Michaux wormwood (*Artemisia michauxiana*), ingested by elk in relation to the total dry herbaceous biomass of that species in the study area was +0.18 in spring, +0.44 in summer, and +0.40 in fall. Similar preference values for this species by sheep were –0.46 in summer and +0.41 in fall (appendix A, table A5). In relation to all herbaceous and woody species, the preference values of Michaux wormwood for elk in 1994 were +0.18 in spring, +0.09 in summer, and +0.65 in fall, and for sheep in 1994 were –0.49 in summer and +0.27 in fall (appendix A, table A6).

Preference values were calculated in 1994 (when both herbaceous and woody species were considered) for elk and domestic sheep feeding sites in aspen communities. These values revealed aspen was the most preferred forage plant by elk in summer (+0.70) and the third most preferred forage species in fall (+0.55) (appendix A, table A7). Aspen ranked sixth in preference (+0.35) as a forage species by sheep in summer 1994. In aspen communities sampled in 1994, red elderberry ranked third in summer (+0.58) and eighth (+0.23) in fall in terms of preferred elk foods, while sheep preferred red elderberry (+0.59) over any other plant in summer (appendix A, table A7).

Electivity for forage in aspen zones indicated a degree of selection for novel food items, as demonstrated in spring 1994 by elk preference, for Nelson's larkspur (*Delphinium nuttallianum*) of +0.76, and yellow salsify (*Tragopogon dubius*) of +0.56 (appendix A, table A7). They were considered novel because Nelson's larkspur appeared in only one (16.7 percent) and yellow salsify in only two (33.3 percent) of the six aspen zone feeding sites considered in spring 1994 (Beck 1996). Based on these preference data, elk apparently selected sites to feed in within the available plant communities where preferred food plants were found, and that at times uncommon species were consumed at rates elevated above common plants.

Ivlev's electivity indices of forage preference were regressed against nutritional fractions (the independent variables). These multiple regression analyses were calculated on those species comprising at least 90 percent of elk and sheep seasonal diets. These results indicate that the percent crude protein was the only variable that contributed significantly ($P < 0.05$) to spring, summer, and fall elk preferences for forage species. Crude protein was never a variable selected in best subsets of regression procedures to determine which variables affected sheep preference (table 19). Crude protein (6.25 x [percent nitrogen]) is considered the most important nutritional component for large herbivores and may indicate overall diet quality as well as providing amino acids for development of new cells for maintenance, growth, reproduction, and lactation (Nelson and Leege 1982).

It is not clear why elk preference for forages depended more on crude protein levels than did the preference by sheep. However, three possible explanations are offered: (1) because elk are wild and free-ranging, they have the ability to locate to areas containing protein-rich forage plants; (2) because sheep are herded, they do not have the same freedom to move to areas and concentrate on proteinaceous forages; and (3) compared to domestic sheep, elk have relatively larger body size and greater requirements for protein needed in lactation, growth, replacement of blood lost to biting fly bites, antler growth, and so forth, so elk prefer plants with high crude protein levels because they require more protein. This last explanation takes in account that elk use learned or innate nutritional wisdom, or euphagia, to select plants that meet nutritional requirements (Flinders 1988). Due to herding, sheep may be restricted in their ability to exercise nutritional wisdom because they are limited to selecting the plants presented to them.

The percent magnesium in preferred forages was an important nutritional fraction in both summer and fall sheep regressions. Only in the regression of nutritional fractions important in the preference of fall elk

Table 19—Multiple regression of Ivlev's electivity index of forage preference values on nutritional fractions[a] of those forage species comprising at least 90 percent of seasonal elk and domestic sheep diets, 1993 and 1994. Seasons were combined in 1993 and 1994. These data were initially subjected to best subsets of regression to select the best model.

Predictor	Coefficient	SE	P	R^2	df	F	P[b]
Elk—Spring				0.59	14	5.26	0.017
Constant	–3.293	0.819	0.002				
ppm Na	–0.009	0.005	0.099				
Percent CP[c]	7.791	3.146	0.031				
Percent H_2O	2.942	1.029	0.016				
Elk—Summer				0.83	17	8.71	0.001
Constant	–3.972	0.705	0.000				
Ca/P	0.025	0.006	0.001				
ppm Na	–0.002	0.000	0.002				
Percent ADF[d]	3.436	0.624	0.000				
Percent CP	4.439	1.092	0.002				
Percent H_2O	2.758	0.599	0.000				
Percent TNC[e]	3.031	1.093	0.018				
Elk—Fall				0.82	9	2.35	0.258
Constant	2.805	1.092	0.083				
Ca/P	0.058	0.022	0.075				
ppm Na	0.005	0.002	0.053				
Percent ADF	–4.850	2.267	0.122				
Percent CP	–22.388	6.671	0.044				
Percent H_2O	3.013	1.455	0.130				
Percent Mg	–511.000	263.200	0.147				
Sheep—Summer				0.25	30	3.01	0.048
Constant	–0.359	0.257	0.174				
ppm Na	–0.002	0.001	0.043				
Percent H_2O	0.558	0.501	0.275				
Percent Mg	148.900	91.260	0.114				
Sheep—Fall				0.50	20	2.97	0.046
Constant	0.584	0.636	0.373				
ppm Na	0.002	0.001	0.086				
Percent ADF	–1.767	1.079	0.122				
Percent Mg	297.300	123.600	0.029				
Percent TNC	–6.123	2.509	0.028				
Year	0.601	0.224	0.017				

[a] Nutritional fraction variables included: CP = crude protein; ADF = acid detergent fiber; TNC = total nonstructural carbohydrates; Ca/P = calcium-to-phosphorous ratio; Mg = magnesium; Na = sodium; and H_2O = water.

[b] Significant regressions ($P < 0.05$).

[c] CP is the percent of nitrogen in each sample x 6.25, since most proteins contain about 16 percent nitrogen.

[d] ADF reflects amounts of carbohydrates not solubilized by acid detergent. These undigestible carbohydrates are cellulose, lignin, lignified nitrogen, cutin, silica, and some pectins.

[e] TNC are the percent of sugars in a sample.

forages was magnesium found as a constituent determining elk forage preference. Natural mineral licks are used by elk and not by sheep (table 20). But sodium-dominated salt placements for sheep are used by both elk and sheep (appendix D, table D2). Magnesium in granulated salt placed for sheep was the third highest fraction but was never greater than 0.18 percent of the total mineral fraction (table 21). Magnesium also ranked third in natural mineral licks but occurred in relatively more abundant levels than in artificial salt placements (tables 20 and 21). At least in spring and summer, elk were able to obtain a sufficient supply of magnesium from natural mineral licks, while domestic sheep depended upon forages to acquire magnesium.

The regression of elk summer preference was the most significant regression (R^2 = 0.83, df = 17, P = 0.001) on preference by elk or sheep. The coefficient of determination for this regression indicated that 83 percent of the variation in elk preference for forages in summer was explained by the calcium-to-phosphorous ratio, ppm sodium, percent acid detergent fiber,

Table 20—Results (ppm = parts per million) derived from testing soils of natural mineral sources used or suspected to be used by elk and/or mule deer in the Willow Creek drainage, 1993 and 1994.

Test	East of Ice Spring[b] (seep)	East Buffalo Spring[b]	West Buffalo Spring[b]	Racetrack Exclosure seep[b]	West of Racetrack Exclosure seep 1[a]	West of Racetrack Exclosure seep 2[a]	Racetrack Spring[b]	Willow by Racetrack[a,c] Confluence Spring	French Hollow Spring[b,d]
Percent sand	42.1	36.1	31.9	41.2	45.0	54.3	52.1	52.3	34.0
Percent silt	29.0	26.9	29.2	37.4	33.7	29.4	21.6	25.3	31.7
Percent clay	28.9	36.9	39.0	21.4	21.3	16.3	26.3	22.3	34.3
Texture	Clay loam	Clay loam	Clay loam	Loam	Loam	Sandy loam	Sandy clay loam	Sandy clay loam	Clay loam
Smell	Mossy bog	Earthy	Sweet	Manure	Extreme manure	Manure	Weak earthy	Strong manure	Earthy
Percent organic matter	6.0	4.8	9.0	35.9	7.1	6.2	3.7	5.3	8.4
pH	7.2	7.7	7.6	7.8	7.3	7.6	7.6	7.8	7.4
EC x 10^3[e]	2.3	0.6	0.9	2.1	1.8	2.3	1.2	0.9	1.6
SAR[f]	0.22	0.02	0.32	0.12	0.16	0.48	0.79	0.63	0.61
Percent $CaCO_3$	12.5	11.3	11.6	25.0	27.2	34.2	12.3	12.4	12.4
ppm SO_4-S (H_2O)	480.8	54.5	166.4	59.9	217.5	380.8	311.3	83.9	135.3
ppm SO_4-S (total)	5,037.5	5,489.7	5,577.5	36,555.0	5,359.2	5,381.0	5,144.0	4,538.0	3,338.0
ppm Ca (H_2O)	421.0	91.0	152.0	347.0	253.0	200.5	85.0	124.0	158.0
ppm Ca (NH_4OAC)	8,850.0	9,400.0	7,520.0	14,120.0	8,230.0	9,840.0	9,020.0	11,450.0	12,350.0
ppm Cl (H_2O)	142.0	20.0	18.0	76.0	214.9	17.4	5.9	6.3	7.0
ppm K (H_2O)	12.0	6.5	15.5	9.0	22.5	11.5	7.5	6.5	23.0
ppm K (NH_4OAC)	124.8	227.2	396.8	70.4	60.8	37.2	87.4	153.8	330.0
ppm Mg (H_2O)	124.5	24.5	37.5	121.5	92.0	92.0	58.5	48.0	55.5
ppm Mg (NH_4OAC)	680.0	810.0	800.0	1,720.0	470.0	550.0	860.0	1,170.0	1,270.0
ppm Na (H_2O)	20.5	1.0	17.0	10.0	11.5	33.0	39.0	32.5	35.0
ppm Na (NH_4OAC)	29.0	24.0	32.4	56.2	16.6	1.2	15.6	22.6	19.2

[a] Elk use suspected.

[b] Elk use documented.

[c] Mule Deer use documented.

[d] Mule Deer use suspected.

[e] EC x 10^3 = a measurement of the salt concentration of the soil based on the ability of the salt in a soil solution to conduct electricity. The salinity level expressed in EC is measured in decisiemens/meter (dS/m) (Brady 1990).

[f] SAR = Sodium adsorbtion ratio. This is a calculation which gives the comparative concentrations of Na^+, Ca^{2+}, and Mg^{2+} in cmol/kg of soil extract. SAR takes into consideration that the adverse effect of Na is moderated by the presence of Ca and Mg ions (Brady 1990).

Table 21—Mineral fractions of granulated salt[a] used to supplement grazing domestic sheep.

Fraction	Minimum	Maximum
	- - - - - - - - - - *Percent*	- - - - - - -
Sodium chloride (NaCl)	93.0	98.0
Calcium (Ca)	0.35	1.35
Magnesium (Mg)	0.06	0.18
Sulphur (S)	0.07	0.17
Potassium (K)	0.03	0.15
Iron (Fe)	0.03	0.08
Phosphorous (P)	0.02	0.07
Iodine (I)	0.001	0.004
Manganese (Mn)	0.0005	0.002
Silicon (Si)	0.0002	0.002
Zinc (Zn)	0.0003	0.001
Copper (Cu)	0.0003	0.0007

[a] Natural trace mineral (NTM) salt. Redmond Clay & Salt Co., Inc., Redmond, UT 84652, (801) 529-7402; (800) 367-7258.

percent crude protein, percent water, and the percent total nonstructural carbohydrates in those forages comprising at least 90 percent of elk diets (table 19). Percent water in preferred forages was important to elk and sheep and was represented in every case by a positive coefficient (table 19). The importance of water in the preference of plants probably reflected the selection of succulent species by elk and sheep. In particular, forbs contained higher water concentrations than graminoids or browse (appendix B, table B2). By comparison, Edge and others (1988) reported that elk foraging behavior in the northern Garnet Mountains of western Montana, during early summer, reflected the abundance and succulence of forage.

A regression of Ivlev's electivity indices on elk and sheep dietary fractions (at least 90 percent) was reported only for 1994 by Beck and others (1996). This regression considered only those species in 1994 seasonal diets (the regression reported in this paper was a compilation of all seasons in 1993 and 1994). In addition, the regression by Beck and others (1996) yielded the best understanding of the effect of woody species in the seasonal diets of elk and sheep because this regression did not include the year (1993) when data were not available pertaining to the amount of browse in elk or sheep diets. Therefore, data from this regression provide an understanding of the role browse plays in providing essential nutrients and the relation of dietary browse to forage preference.

The combined regression of 1993 and 1994 demonstrated crude protein to be significant ($P < 0.05$) in predicting elk forage preference in all seasons (spring, summer, and fall). Similarly, the 1994 regression revealed that crude protein was a variable positively identified in all 1994 elk regressions on forage preference. However, percent crude protein was only significant ($P < 0.05$) in summer. Crude protein was also found to be significant ($P < 0.05$) in predicting sheep forage selection in fall but was not a variable selected in summer sheep preference (Beck and others 1996). Protein in browse forages tends to remain much more constant in concentration throughout a yearly growth cycle than does protein content in grasses and forbs (Vallentine 1990). Our data support this trend, with crude protein levels remaining more constant in browse than in herbaceous species from spring to fall (appendix B, table B1). Thus, in the case of crude protein, the inclusion of browse into the regression did reveal an effect on elk and sheep diet preference.

Other differences in preference in these two regressions (combined 1993 and 1994: and 1994 only) can be explained by fluctuations in nutrient fractions between woody and herbaceous forage sources (appendix B, tables B1 and B2). For example, levels of total nonstructural carbohydrates, magnesium, and water differed from summer to fall in browse and herbaceous species; these three nutrients tended to decrease in herbaceous plants and be more stable in woody plants (appendix B, tables B1 and B2). That elk and sheep switched their foraging activities from graminoids and forbs to the more nutrient-stable browse from earlier in the growing season (spring and summer) to fall can be seen in corresponding fluctuations in their dietary fractions (fig. 11). Thus, some additional conclusions can be drawn concerning nutrient concentrations in preferred forage species in the 1994 regression (Beck and others 1996) because the effect of browse in elk and sheep dietary fractions was considered equally between the two other forage choices (graminoids and forbs). In addition, results from Beck and others (1996) regression demonstrated that elk and domestic sheep preferred to ingest those plants that held more reliable concentrations of essential nutrients.

Poisonous Properties of Vegetation in the Study Area—Brotherson and others (1980) reported that 41 percent of poisonous plants identified in Utah are from the Compositae and Leguminosae families. Data from Willow Creek plants revealed 39.4 percent of composites and 66.7 percent of legumes in the study area contain toxins or are suspect of containing toxins. Forty (21.3 percent) of all identified plant species in the study area contain known toxins or can be mechanically injurious to ungulates. Seventy-three (38.8 percent) of all plants classified in the study area are known or suspected to be toxic or to be mechanically injurious to grazing animals (appendix B, table B3). Poisonous properties of all plant species identified in the study area are shown in appendix B, table B3. Most of these poisonous plants were avoided by elk and sheep.

Several important dietary species including red elderberry, Nelson's larkspur, western larkspur (*Delphinium occidentale*), and chokecherry (*Prunus virginiana*) all contain toxins (appendix B, table B3). Elk used 100.0 percent of chokecherry individuals found in summer 1993 elk feeding sites. Dietary use of mature red elderberry individuals by elk and sheep in summer and fall of 1993 and 1994 at feeding sites ranged from 44.5 to 100.0 percent. In summer 1993, sheep used 28.0 percent, and in spring 1993, elk used 2.0 percent of Nelson's larkspur individuals; in summer 1993, sheep fed on 100.0 percent of western larkspur individuals in feeding sites (appendix A, table A2). Red elderberry had one of the highest elk and sheep preference index values (1994 elk, summer = +0.93, fall = +0.23; 1994 sheep, summer = +0.62, fall = +0.59) of all species (appendix A, table A6). It is not yet clear why plants containing toxins such as alkaloids (larkspurs and red elderberry), nitrates (red elderberry), and cyanic acid (chokecherry and red elderberry) (appendix B, table B3) are favorite forages of elk and sheep. Studies in zoopharmacognosy may explain that elk and sheep eat these plants to obtain natural medicines. Predictably, some poisonous plants such as stinging nettle (*Urtica dioica*) (appendix B, table B3) were completely avoided by elk and sheep (appendix A, tables A2, A3, and A6).

Plant Communities and Seasonal Standing Herbaceous Biomass—Thirty-one plant communities were identified and of these, eight aspen community types comprised 25.8 percent of the total communities sampled (appendix C, table C1). Feeding sites were analyzed in 29 (93.5 percent) of the 31 plant community types (appendix C, tables C1 and C2). Utilization of biomass by plant community and percent of feeding site locations by plant community showed patterns of seasonal use. For example, in spring 1994, 10.0 percent of sampled elk feeding sites were in the aspen-forb plant community type, and biomass use of available vegetation in this community was 5.7 percent. In summer 1994, 9.1 percent of elk feeding site locations were in the aspen-forb plant community type, and elk consumed 2.2 percent of the available standing biomass in feeding sites sampled in this community type (appendix C, table C1). Other plant communities important to elk and domestic sheep were aspen-grass, aspen-snowberry, grass meadow, sagebrush-grass, sagebrush-mixed brush, mixed-brush, and *Chrysothamnus viscidiflorus*-grass (appendix C, table C1).

Snowberry-forb plant communities had the largest quantity of standing biomass. In summer 1993, an average of 1,867 kg per ha (1,663 lb per acre) of herbaceous standing biomass occured in the snowberry-forb community type and in summer 1994, this plant community provided an average of 2,113 kg per ha (1,883 lb per acre) of herbaceous standing biomass (appendix C, table C2). The community with the second highest mean kg per ha of standing herbaceous biomass was furnished by the riparian type. In spring 1994, this type yielded 2,112 kg per ha (1,882 lb per acre) of standing herbaceous biomass, and in summer 1994 this amount was 1,751 kg per ha (1,560 lb per acre) (appendix C, table C2).

Houston (1954) attributed variations in herbaceous forage production (560 to 4,480 kg per ha) under aspen understories to environmental differences, levels of livestock grazing, and plant community successional status. The average ovendry herbaceous seasonal standing biomass in Willow Creek aspen types ranged from a high of 1,484 kg per ha in the aspen-forb type in summer of 1994 to 129 kg per ha in the herb depleted aspen-mixed brush type in spring of 1993 (appendix C, table C2). Mueggler (1985) reported a researcher had found understory production of aspen communities on the Manti-LaSal National Forest in central Utah ranged from 785 to 1,905 kg per ha. Other research on the Wasatch National Forest in northern Utah found the air-dry production of undergrowth vegetation in aspen forests ranged from 449 to 2,300 kg per ha with an average of 1,219 ± 87 kg per ha.

Estimates of standing herbaceous biomass (not total production) in aspen understories in Willow Creek agree well with that found in nearby forests. These data are especially useful as these values of standing biomass under aspen types were derived from use estimates of biomass removed by elk and sheep herbivory, clipping the remaining vegetation, and after drying the clippings, calculating the original dry biomass at each site. Data from other aspen studies support estimates of ungulate use of biomass from the Willow Creek study and thus add reliability to results of utilization in the study area. Narrow 95 percent confidence intervals reported in table 13 on the percent use of standing biomass at elk and sheep feeding sites add more validity to vegetation sampling methods used in Willow Creek.

Browse Use and Density in Plant Communities—More intensive analyses of woody species found in 1994 feeding sites assisted in determining density (number of woody stems by species per hectare and acre), percent cover, mean height (m), percent use of woody plant biomass and percent use of annual growth (appendix C, table C3). Percent use of woody biomass was an ocular estimate of the percent removed from each individual woody species found in 22.6 m^2 belt transects positioned on feeding sites of elk and sheep. Percent use of annual growth was an ocular estimate of the percent of annual biomass removed by elk or sheep herbivory on the nearest individual (closest to the center of each feeding site) of each woody species sampled. Browsing of woody plants by elk in spring was nominal, and elk and sheep browsing was greatest in summer and fall. For example, elk herbivory on aspen in aspen-snowberry communities in spring was 0.0 percent (percent use of biomass and percent use of annual growth). In summer 1994, elk consumed 1.0 percent of aspen biomass in feeding sites sampled in aspen-snowberry communities. Use of aspen by elk in fall 1994 at feeding sites in aspen-snowberry communities reflected 2.0 percent utilization of available aspen biomass, with 34.0 percent of the annual aspen growth being eaten. The highest mean use of woody plant biomass was 68.0 percent, and the highest mean use of annual growth was 78.0 percent on red elderberry at a fall 1994 sheep feeding site in a mixed-brush community (appendix C, table C3). The average percent use of red elderberry biomass in summer 1994 by elk was 9.0 percent and by sheep was 25.3 percent. In fall 1994, use of red elderberry biomass was 12.0 percent by elk and 47.0 percent by sheep (appendix A, table A3).

Viscid rabbitbrush exhibited the highest spatial density at 35,904 per ha (14,530 per acre) in *Chrysothamnus viscidiflorus*-mixed brush-grass community types sampled at sheep feeding sites in summer 1994. This shrub species also had the second highest spatial density at 33,245 per ha (13,454 per acre) in mixed brush plant communities sampled at sheep feeding sites in summer 1994 (appendix C, table C3). Other species with relatively high spatial densities were big sagebrush, mountain snowberry, red elderberry, aspen, wax currant (*Ribes cereum*), gooseberry currant (*Ribes montigenum*), and silver sagebrush (appendix C, table C3).

Elk Feeding Site Selection—Edge and others (1988) evaluated elk selection of feeding sites based on forage species abundance. Feeding sites were defined as a site with more than or equal to 50 instances of use.

These results were similar to those of this study in that forbs and shrubs were the predominant elk forage classes during summer. By performing a discrimant analysis to test the hypothesis of equal mean species availability between random sites and seasonal feeding sites, Edge and others found that percent availability of forage species differed significantly between elk feeding sites and random sites in early and late summer. Grover and Thompson (1986) applied regression analyses to factors that influenced spring elk feeding site selection in the Elkhorn Mountains on the Helena National Forest, MT. Elk feeding use was the dependent variable and was estimated by recording the percent use of three dominant bunchgrasses by elk. The four variables that accounted for 65 percent of the variation in elk feeding distributions over the two study area pastures were (1) cattle use, (2) distance from the nearest road, (3) density of bunch grass plants, and (4) distance to cover. In their study, elk appeared to react favorably to previous cattle grazing. By comparison, Willms and McClean (1978) found that cattle grazing in the fall removed mature stalks of grasses fed on in the spring by tame mule deer. This increased the availability of these grasses to deer and increased crude protein levels by 2 to 3 percent over foliage where mature stalks had not been removed.

In their research regarding influences of weather on elk use of spring and summer habitat, Marcum and Scott (1985) concluded that during late spring and summer when snow was absent, elk apparently responded primarily to forage conditions. Feeding activities accounted for 44.3 percent (45.8 percent for bedding) of the composite time budget of seven female elk (based on 17, 24-hour activity patterns) studied in Yellowstone National Park (Craighead and others 1973). Thus, selection of feeding sites, on a seasonal basis, should say more about elk use of habitat and forage than any other single variable.

Multiple regression analyses of percent herbaceous forage use (Grover and Thompson 1986) when applied to habitat and vegetation variables explained why feeding site locations were selected on a seasonal and yearly basis by elk and sheep (table 22). Use of multiple regression analyses seemed especially wise when considering findings of Shannon and others (1975) concerning inferences made on simple correlations between Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) locations and single habitat variables. Because variables were interconnected, results of simple correlations (r) did not take into account effects of related variables on each other and often led to different inferences than those from partial (r_i) and multiple correlations (R^2) computed for the same variables.

In the Willow Creek study area, particular micro and macrohabitat factors were assessed in relationship to elk and sheep feeding sites. In spring, 52 percent ($R^2 = 0.52$, df = 18, $P = 0.009$) of the variation in elk use of herbaceous biomass at feeding sites was attributed to east-west-facing exposures, distance to a road less than or equal to 1,000 m from feeding sites, and the grams of herbaceous biomass found at feeding sites (table 22). None of these three independent variables were significantly correlated to each other ($P > 0.05$) (table 23).

Distances of feeding sites to ecological variables may be misunderstood and therefore need some clarification (appendix D, table D1). A pattern of elk moving farther from roads occurred from spring (1993, mean = 339.2 m, SD = 260.2; 1994, mean = 457.7 m, SD = 326.7) to fall (1993, mean = 482.3 m, SD = 290.7; 1994, mean = 669.0 m, SD = 405.9) (appendix D, table D1). One possible reason that elk feeding site selection in spring was affected by the distance to a road may be that salt placements used by elk were typically close to roads (mean = 438.5 m, SD = 456.9) (appendix D, table D2). At spring elk feeding sites, distance to a road and distance to a salt lick were not significantly correlated ($P > 0.05$) (table 23); however, the distance to a salt placement was significantly correlated ($r = 0.46$, $P < 0.05$) with the distance to a road at sheep feeding sites analyzed in the study area in summer and fall (table 24). Because elk use these sheep salting placements the following spring, elk foraging near roads would be adjacent to sodium supplements.

West-facing aspects (270°) relate to a negative value and easterly aspects (90°) to a positive value following sine transformations because these corresponding degrees oppose each other in a circular arrangement. South-facing aspects (180°) correspond to negative values and north-facing (360°) aspects to positive values following cosine transformations because these corresponding degrees oppose each other in a circular arrangement (Smith 1991). The distance to salt was negatively correlated with the sine transformation of the degree of aspects ($r = -0.51$, $P < 0.05$) at spring elk feeding sites (table 23). These data indicate that elk selected feeding locations in spring where salt placements were farther from westerly aspects.

An additional effect that roads had on the selection of elk feeding sites in spring can be seen by a spatial inspection of spring elk concentrations. This reveals most elk were in the south and west portions of the study area; these areas have the highest road densities in the drainage (maps 1 and 2). Roads received little use by humans in spring, and as a result elk often used roads as travel corridors at this time of year. Areas in the south and west of the study area are dominated by southerly aspects at lower elevations. As a result, plant growth began earlier here. Standing herbaceous biomass in these areas exceeded other, less favored sites in spring. In spring, then, elk fed at

Table 22—Multiple regression of the percent use of herbaceous biomass at elk and domestic sheep feeding sites on environmental variables present at feeding sites, 1993 and 1994. These data reveal important aspects of feeding site selection. All 1993 and 1994 elk spring, elk summer and fall, and domestic sheep summer and fall values were combined to provide more observations. These data were initially subjected to best subsets of regression to select the best model.

Predictor	Coefficient	SE	*P*	R^2	df	*F*	*P*
Elk—spring				0.52	18	5.50	0.009
Constant	0.033	0.009	0.002				
Aspect° (sine)[a]	–0.010	0.007	0.153				
Distance to road (m)	0.000	0.000	0.003				
Herbaceous biomass (g)	0.000	0.000	0.015				
Elk—summer and fall				0.59	29	3.74	0.007
Constant	0.363	0.258	0.174				
Aspect° (cosine)[a]	0.048	0.025	0.063				
Aspect° (sine)[a]	–0.016	0.014	0.256				
Elevation (m)	0.000	0.000	0.079				
Distance to ridgetop (m)	0.000	0.000	0.006				
Herbaceous biomass (g)	0.000	0.000	0.071				
Percent vegetative ground cover	0.256	0.079	0.004				
Season and year	0.023	0.010	0.032				
Slope°	–0.003	0.001	0.037				
Sheep—summer and fall				0.51	18	2.72	0.068
Constant	0.517	0.330	0.141				
Aspect° (cosine)[a]	–0.022	0.018	0.253				
Elevation (m)	0.000	0.000	0.262				
Herbaceous biomass (g)	0.001	0.000	0.025				
Distance to sheepherder (m)	0.000	0.000	0.253				
Distance to salt (m)	0.000	0.000	0.033				

[a] The degree of aspects at elk and domestic sheep feeding site locations were sine and cosine transformed. Since sine and cosine are cofunctions of each other, it follows that the cofunctions of complementary angles are equal (Smith 1991). Sine transformations pertain to east-west aspects. Cosine transformations pertain to north-south aspects.

locations offering optimal vegetation and mineral conditions.

North-south-facing aspects, east-west-facing aspects, elevation (m), distance to a ridgetop, the amount of herbaceous biomass (g) found at feeding sites, the percent of vegetative ground cover occurring at feeding sites, the season and year of feed site sampling, and the degree of slope were all selected independent variables that contributed 59 percent ($R^2 = 0.59$, df = 29, $P = 0.007$) to the variation in elk feeding site selection in summer and fall (table 22). Elk seemed to be feeding in areas that afforded greater vegetational ground cover and biomass. By comparison, Wickstrom and others (1984) found tame elk were reluctant to feed in grass swards of low biomass, regardless of digestibility. Using a model of energy intake, Fryxell (1991) estimated that the daily rate of energy gain for elk should be highest when they feed in grasslands with 1,000 to 1,100 kg per ha of forage. In Willow Creek a similar relationship of elk feeding in areas of high standing biomass per hectare was seen (appendix C, tables C1 and C2).

All other variables in this regression model contributed, to an extent, to the amount of vegetation available at elk feeding sites. For example, the percent of vegetative ground cover at elk feeding sites in summer and fall was positively correlated with the season and year of feed site sampling ($r = 0.40$, $P < 0.05$) and negatively correlated with the distance to a ridge ($r = -0.51$, $P < 0.05$) (table 23). Differences seen in seasonal standing biomass between years (appendix C, table C2) account for variations in plant cover and demonstrate that elk often select patches of vegetation characterized by high plant cover. Percent of vegetative ground cover increased as the distance from a ridgetop decreased. This is probably related to aspen stands, which typically were close to ridgetops and normally exhibited high plant understory cover (appendix C, table C2).

There was a significant, negative correlation ($r = -0.56$, $P < 0.05$) between the percent vegetative ground cover at summer and fall elk feeding sites and the mean distance to horizontal cover (table 23). Interpretation of these results indicates that as the percent of

Table 23—Matrix of simple correlation coefficients of environmental variables[a] measured at elk (spring, and summer and fall combined) feeding sites, 1993 and 1994. All variables were subjected to multiple regression analyses, except H_2O and salt.

Variable	Asp C	Asp S	Edge	Elev	Herb	H_20	Mean HC	Percent veg	Plant	Ridge	Road	Salt	Se/yr	Slope
Elk—spring														
Asp C														
Asp S	0.04													
Edge	–0.08	0.34												
Elev	0.49[b]	0.04	–0.24											
Herb	–0.11	–0.20	–0.22	–0.31										
H_2O	0.39	0.14	0.01	0.27	–0.41									
Mean HC	–0.12	0.28	0.84[b]	–0.38	0.09	–0.09								
Percent veg	–0.25	–0.57[b]	–0.19	–0.31	0.55[b]	–0.07	–0.09							
Plant	0.07	0.15	–0.25	–0.06	0.38	0.24	–0.21	0.31						
Ridge	0.04	–0.08	0.18	–0.38	0.00	–0.01	0.00	0.00	0.00					
Road	–0.32	–0.04	–0.33	–0.34	0.33	–0.34	–0.34	0.06	0.16	0.09				
Salt	0.08	–0.51[b]	–0.36	0.20	–0.27	0.54	–0.45	0.37	0.44	0.08	0.00			
Se/yr	–0.08	0.06	0.13	–0.06	0.31	0.23	0.17	0.06	0.57[b]	–0.04	0.05	1.00[c]		
Slope	–0.12	–0.19	–0.24	0.13	–0.43[b]	0.07	–0.44[b]	–0.12	–0.18	0.43[b]	0.36	0.41	–0.32	
Time	–0.10	0.05	0.27	–0.40	0.31	–0.07	0.45[b]	0.32	–0.06	–0.10	–0.03	–0.36	0.17	–0.30
Elk—summer and fall														
Asp C														
Asp S	0.38[b]													
Edge	–0.10	0.08												
Elev	0.12	–0.18	0.04											
Herb	–0.01	–0.22	0.01	0.15										
H_2O	–0.01	–0.09	–0.17	0.33	0.03									
Mean HC	0.06	0.00	0.10	–0.14	–0.04	–0.25								
Percent veg	–0.30	0.06	0.19	0.20	0.12	0.40[b]	–0.56[b]							
Plant	0.05	0.16	0.12	–0.14	–0.22	–0.20	–0.52[b]	0.21						
Ridge	0.12	–0.05	0.23	–0.11	0.24	–0.37[b]	0.69[b]	–0.51[b]	–0.49[b]					
Road	0.03	0.09	–0.30	–0.40	–0.01	0.31	–0.54[b]	0.22	0.24	–0.46[b]				
Salt	–0.07	0.41	–0.30	–0.45	–0.60	–0.48	–0.34	0.40	0.39	–0.51	–0.31			
Se/yr	–0.08	0.31	0.29	–0.13	0.02	–0.30	–0.44[b]	0.40[b]	0.73[b]	–0.38[b]	–0.03	0.15		
Slope	0.30	0.15	–0.08	–0.09	0.11	–0.44[b]	–0.32	–0.03	0.48[b]	–0.17	0.06	0.19	0.27	
Time	0.01	0.11	–0.11	–0.29	–0.13	–0.31	0.34	–0.28	–0.11	0.30	–0.30	0.30	–0.06	–0.03

[a] Variables are: Asp C = cosine transformation of aspect°; Asp S = sine transformation of aspect°; Edge = distance to habitat edge (m); Elev = elevation (m); Herb = dry herbaceous biomass (g) clipped at feeding sites; H_2O = distance to water (m); Mean HC = mean distance to horizontal obscurity cover; Percent veg = percent of ground cover consisting of plants at feeding sites; Plant = the number of plant species occurring at feeding sites; Ridge = distance to ridgetop (m); Road = distance to road (m); Salt = distance to salt or natural mineral lick (m); Se/yr = season and year feeding sites were analyzed; Slope = slope° at feeding sites; and, Time = time of day feeding sites were located.

[b] Significant correlations ($P < 0.05$).

[c] Values for Se/yr were the same in all correlations with salt in spring, therefore, this correlation is not valid.

vegetative ground cover increased, the distance to mean horizontal cover decreased. This implies that the closer to mean horizontal obscurity cover, the more plant cover there was on the ground, and that elk selected these feeding sites. This holds true with Knowles and Campbell (1982, in Grover and Thompson 1986) who conveyed the fact that regardless of forage conditions, elk require security prior to grazing.

Domestic Sheep Feeding Site Selection—North-south-facing aspects, elevation, herbaceous biomass (g) at feeding sites, distance to a sheepherder, and distance to a salt placement accounted for 51 percent ($R^2 = 0.51$, df = 18, $P = 0.068$) of the variation in sheep feeding site selection in summer and fall. Habitat factors that affected the selection of feeding sites by sheep have to be considered in relation to management by the herder. For instance, the distance to a herder from summer and fall sheep feeding sites was significantly correlated with the grams of herbaceous biomass found at sheep feeding sites ($r = 0.50, P < 0.05$) and with the distance to water ($r = 0.56, P < 0.05$) (table 24). These data suggest that when sheep were feeding near a sheepherder, they were also in areas with high amounts of herbaceous biomass and near a water source because these were the areas where herders moved bands of sheep. Herding also dictated the elevation and aspect in which sheep bands grazed.

The only other variable that contributed significantly to the regression equation besides the amount of herbaceous biomass at feeding sites ($P = 0.025$) was the distance to salt ($P = 0.033$) (table 22). The distance to salt from sheep feeding sites in summer and fall was significantly correlated with the distance to water ($r = 0.46, P < 0.05$) and the distance to a road ($r = 0.46$,

Table 24—Matrix of simple correlation coefficients of environmental variables[a] measured at domestic sheep (summer and fall combined) feeding sites, 1993 and 1994. All variables were subjected to multiple regression analyses, except H_2O, ridge, and edge.

Variable	Asp C	Asp S	Edge	Elev	Herb	Herder	H_2O	Percent veg	Plant	Ridge	Road	Salt	Se/yr	Slope
Sheep—summer and fall														
Asp C														
Asp S	0.30													
Edge	–0.15	–0.05												
Elev	0.05	0.17	–0.31[b]											
Herb	0.01	0.05	–0.19	–0.19										
Herder	0.10	–0.18	–0.01	0.01	0.50[b]									
H_2O	0.25	0.08	0.04	0.30	0.22	0.56[b]								
Percent veg	0.07	0.23	0.14	–0.25	0.28	0.29	0.16							
Plant	0.32	0.17	–0.36[b]	0.15	0.01	0.11	0.09	0.12						
Ridge	0.02	0.10	0.15	0.01	0.01	0.00	–0.06	0.08	–0.07					
Road	–0.03	–0.19	–0.28	–0.18	0.05	0.33	–0.16	0.22	0.11	–0.05				
Salt	–0.01	–0.03	–0.32	0.11	0.21	0.29	0.46[b]	0.00	0.05	–0.30	0.46[b]			
Se/yr	–0.02	–0.01	0.26	–0.09	–0.09	0.22	0.09	0.25	0.04	–0.14	–0.01	–0.12		
Slope	0.06	0.06	–0.30[b]	0.26	–0.28	0.05	–0.14	–0.33[b]	0.01	–0.01	0.34[b]	0.33	0.04	
Time	0.03	0.00	–0.08	0.25	0.05	–0.15	0.08	–0.18	0.00	–0.19	–0.05	0.19	–0.14	–0.04

[a] Variables are: Asp C = cosine transformation of aspect°; Asp S = sine transformation of aspect°; Edge = distance to habitat edge (m); Elev = elevation (m); Herb = dry herbaceous biomass (g) clipped at feeding sites; Herder = distance to sheepherder (m); H_2O = distance to water (m); Percent veg = percent of ground cover consisting of plants at feeding sites; Plant = the number of plant species occurring at feeding sites; Ridge = distance to ridgetop (m); Road = distance to road (m); Salt = distance to salt or natural mineral lick (m); Se/yr = season and year feeding sites were analyzed; Slope = slope° at feeding sites; and, time = time of day feeding sites were located.

[b] Significant correlations ($P < 0.05$).

$P < 0.05$) (table 24). Both of these correlations are related to sheep herding because sheep typically used salt placed by herders close to water (mean = 349.8 m, SD = 406.5) and roads (mean = 229.0 m, SD = 329.7) (appendix D, table D2).

Ruyle and Dwyer (1985) reported the number of sheep feeding station intervals less than 10 seconds in duration increased as grazing progressed in conjunction with a significantly reduced amount of forage in 0.4 ha paddocks on mountain rangeland in southwestern Utah. This trend continued as sheep grazed with cattle. However, the time was longer at feeding station intervals than when sheep grazed alone. Ruyle and Dwyer suggested that as forage is depleted later in the grazing season, sheep will move more and feed at each feeding interval for shorter periods. Thus, the amount of herbaceous biomass at sheep feeding sites appears to relate to herder activities because herders often moved their herds to those areas where vegetation was most abundant to provide maximal grazing opportunities. This point is further demonstrated because sheep were closer to human activities (mainly herding) in fall 1994 (mean = 487.7 m, SD = 269.5) than in summer 1994 (1994 mean = 557.8 m, SD = 303.0) (appendix D, table D1).

Salting Locations

The first observation of elk eating salt-impregnated soil was on 10 June 1993 when three cow elk were observed eating soil at a sheep salting rock adjacent to the fenced spring (commonly referred to as Ice Spring) in section 32 of unit 1 of the McKinney allotment (maps 1 and 2). Subsequent sightings of elk eating soil at salting locations caused researchers to speculate that elk foraging and other activities in the drainage may be influenced to some degree by these salting points.

Granulated salt distributed at salting locations consisted almost entirely of sodium chloride (NaCl); this fraction ranged from 93.0 to 98.0 percent (table 21). This fraction would amply satisfy the National Research Council (1985) requirements of 0.09 to 0.18 percent sodium content of dietary, dry matter for domestic sheep. The Council indicated that rangeland ewes are commonly provided 220 to 340 g of salt per month.

A typical sheep salting scenario in the drainage was a fallen aspen log with a groove (notched out by an axe) running along the top surface. Less often, salt was placed on rocks or in tires cut in half. Occasionally, fallen and notched aspen logs that had been used previously as salt locations were found. The soil adjacent to these older salting sites was covered with vegetation. These sites were assessed to not be active, and thus were not classified.

The sheer magnitude of salt locations within the Willow Creek drainage became apparent from travels throughout the work area. Numerous photographs of sheep salting logs, rocks, and soil around salting tires revealed digging and chewing of rock, soil, and wood. Data collection addressed factors of sheep salting placements in the study area including associated ecological factors and how herbivores used these sites.

Data forms were used to document the distance to known sheep salting locations or natural mineral sources less than or equal to 1,000 m from the location of elk and sheep or such resource features as water developments and sheep bed grounds.

Ninety salting locations were sampled in and directly adjacent (Trail Hollow allotment) to the study area and are arrayed on map 2. The number of salting locations sampled per allotment are as follows: five (5.6 percent) in Beaver Creek; six (6.7 percent) in unit 5 of the Broad Hollow/Pete's Knoll allotment; 10 (11.1 percent) in Cabin Springs; 15 (16.7 percent) in Center Canyon; 11 (12.2 percent) in Davis; five (5.6 percent) in unit 3 of the Ingram; 28 (31.1 percent) in McKinney; eight (8.9 percent) in Road Hollow; and 2 (2.0 percent) in Trail Hollow (adjacent to unit 1 of the Davis allotment) (map 2). Of these, sign (tracks or pellets) of elk was found at 54.4 percent, mule deer at 25.6 percent, and sheep at 29.0 percent. No ruminant sign was found at 11.1 percent of salting locations. Elk and sheep sign were found together at 3.3 percent, elk and mule deer sign at 17.8 percent, and mule deer and sheep sign at 2.2 percent of all salting locations (appendix D,table D2). Thus, elk and mule deer may be more willing to use salt licks at the same time. Because this behavior was never observed and owing to the aggressive nature of elk toward each other at these salt licks, it seems that when approached at common salt licks, elk would probably drive mule deer from these licks.

Visits by sheep, elk, and deer to salting placements were probably at different times, due to the diurnal nature of sheep activity and the crepuscular and nocturnal behavior of wild cervids. Dalke and others (1965) reported groups of five cattle and five elk, or less, used salt licks without any animosity, but when 10 or more domestic cows were present, elk were usually driven away. No sightings of elk and sheep using the same salt placements were observed in Willow Creek in 1993 or 1994, but due to the double presence of elk and sheep tracks at 3.3 percent of the analyzed sites this may occur. Evidence provided by Dalke and others seems to indicate that groups of sheep would discourage elk from using the same salt sources at the same time.

In their study of elk and cattle use of, and interactions on salt block placements in Idaho, Dalke and others (1965) reported elk developed a noticeable salt drive late in May, that peaked in June, 2 to 3 weeks after they began foraging on fresh vegetation. Elk ranged farther from salting locations prior to mid-May because elk appetites for fresh vegetation were greater at that time than their desire for salt. In their study of salt drives in white-tailed deer, Weeks and Kirkpatrick (1976) suggested the high intake of water and potassium associated with a spring diet of succulent forage creates a temporary sodium imbalance, and hence induces a salt drive early in the growing season. According to Geist (1971), such spring salt drives in mountain sheep also may help replace skeletal minerals metabolized during winter.

According to Skovlin (1982:391): "Salt use by elk, as with many other ungulate species, is primarily a habit-formed luxury." Skovlin held no doubt that Rocky Mountain elk are attracted to salt placed by humans, but the fact that they thrive without it is equally certain. Edge and others (1988) took advantage of the attraction of elk to salt by luring elk into corral-type traps baited with salt to facilitate radio-collar attachment. The fact that salt (NaCl) is a luxury and not necessary for elk to inhabit an area was demonstrated by Dalke and others (1965) who reported that more migrant elk remained longer in certain areas than others because of choice vegetation, less disturbance by cattle and people, and elevational location rather than the presence of salt. White-tailed deer in New Hampshire (Pletscher 1987) and moose (*Alces alces*) in Ontario (Fraser and Thomas 1982) have been reported to use salt that was applied to de-ice roads. Shannon and others (1975) related the importance of salt to bighorn sheep habitat selection in southeastern British Columbia from January to March and April to June. Results from simple and partial correlations suggested that sheep had an attraction for salt. Salt also attracts many kinds of rodents (Robinson and Bolen 1989). A Uinta ground squirrel (*Spermophilus armatus*) was observed eating damp soil at a salt lick adjacent to the Racetrack Corral on 25 May 1994.

Hulet (1983) reported the occurrence of salting areas for domestic sheep was an important factor for lek establishment by sage grouse (*Centrocercus urophasianus*) in southeastern Idaho at the U.S. Sheep Experiment Station because 75 percent of the leks were at sheep salting sites. In this study, sage grouse hens, but not males, were observed to congregate at leks where salt had been spread out and to peck at the ground apparently to ingest salt-impregnated soil. These hens engaged in this behavior even if the position of the salt lick was not near the center of the lek. The center of the lek is where the master cock is thought to be located (Johnsgard 1973).

Stockstad and others (1953) conducted mineral cafeteria and soil impregnation studies in a rich mineral lick area in western Montana to assess the use of various minerals by elk, mule deer, white-tailed deer, and mountain goat (*Oreamnos americanus*). An index rating based on the sum of the percent frequency and percent of mixture consumed multiplied by 100 revealed that all sodium compounds received much greater use than did any other compound in cafeteria and soil impregnation tests. Thus, they concluded that sodium was the element preferred by the big game animals in all of their mineral lick study areas.

Vallentine (1990) defined a C-4 plant as employing the dicarboxylic acid pathway of CO_2 assimilation during photosynthesis (Salisbury and Ross 1992). These plants (C-4) are commonly referred to as warm season plants. Salisbury and Ross speculated that probably only in C-4 plants (most halophytes) and some succulent plants that fix CO_2 in photosynthesis via the crassulacean acid metabolism pathway (referred to as CAM and found in arid locales) require sodium as a micronutrient. Stockstad and others (1953) discussed the fact that experiments in plant physiology at that time had shown that plant life, with the exception of halophytic species, absorb only a small percentage of the sodium present in the soil. Most plants will not contain enough sodium to satisfy nutritional requirements of grazing animals, so human-placed salt is readily accepted by ungulates. Adult moose at Isle Royal National Park, MI, obtained 94 to 96 percent of their sodium intake from aquatic plants that were available for only 30 percent of the year and that contained sodium levels an order of magnitude or two higher than terrestrial species (Belovsky and Jordan 1981). The reliance of this moose herd on sodium derived from aquatic plants was so high that moose retained enough sodium during the rest of the year to avoid deficiency, support new growth in spring, sustain gestational sodium requirements, and support early lactation in reproducing females (Belovsky and Jordan 1981).

In 1993, Willow Creek elk were found on 21 (33.3 percent) and in 1994 on 47 (78.3 percent) occasions less than or equal to 1,000 m from a salt or natural mineral source. By comparison, sheep in 1993 were located on 15 (46.9 percent) and in 1994 on 29 (85.3 percent) occasions less than or equal to 1,000 m from a salt or natural mineral lick (appendix D, table D1). The proportionate and actual higher number of elk and sheep locations less than or equal to 1,000 m from a source of salt or minerals in 1994 reflects the greater awareness of researchers to the whereabouts of salt locations in the study area. Sheep were found more often (13.6 percent in 1993; 7.0 percent in 1994) than elk to be within 1,000 m from a salt or mineral lick (appendix D, table D1). For those elk locations less than or equal to 1,000 m from a salt source, elk were found an average of 251.7 m (SD = 179.3) in 1993 and 387.9 m (SD = 294.6) in 1994 from a salt or natural mineral lick (appendix D, table D1). For those sheep locations less than or equal to 1,000 m from a salt source, sheep were found an average of 372.3 m (SD = 271.5) in 1993 and 465.6 m (SD = 274.5) in 1994 from a salt or natural mineral lick (appendix D, table D1). For those elk and sheep located less than or equal to 1,000 m from a salt source, mean elk locations were 120.6 m closer to salt licks in 1993 and 77.7 m closer in 1994 to salt licks than sheep (appendix D, table D1).

All salting locations were on slight to moderate slopes (less than or equal to 25°) and the average elevation was 2,731 m (SD = 122.9) (table 25). Salting sites on north, northeast, east, and northwest aspects were frequented 66.7 percent by elk, 52.1 percent by deer, and 55.1 percent by sheep. Salting sites positioned on southeast, east, southwest, and west exposures were selected 33.4 percent by elk, 47.8 percent by deer, and 44.8 percent by sheep (table 25). The 14.6 percent increased use by elk over deer at salting locations on north, northeast, east, and northwest aspects (table 25) may support results presented by Hanley (1980) who found that black-tailed deer exhibited a significant preference for xeric habitat patches, and elk exhibited a highly significant preference for mesic habitat patches. Mean elevations of salting locations used by deer were 2,773.3 m (SD = 106.9), while salt licks used by elk were 2,739.7 m (SD = 106.2), and sheep used salt grounds an average of 2,728.8 m (SD = 123.2) in elevation (table 25).

Salt locations, which at the time of inspection had not been used by herbivores, were the lowest in mean elevation (2,683.7 m, SD = 194.8 m) (table 25) and the farthest from roads (mean = 808.1 m, SD = 800.2) (appendix D, table D2). Salt grounds farther from roads, sheep camps, and ridgetops were probably not supplied regularly with salt, hence lowering their attractiveness to elk, deer, and sheep. Natural mineral locations are identified on map 2. By comparing the seasonal movements of elk in 1994 on this map

Table 25—Seasonal sample sizes and percents of aspect and slope use and mean elevation (m, ft in parentheses) of salting locations sampled in the Willow Creek drainage and used by elk, mule deer, domestic sheep, and not used by animals, 1993 and 1994.

		Aspect								Degree of slope			Elevation (m)	
Animal	n	N	NE	E	SE	S	SW	W	NW	0-10	11-25	≥26	Mean	SD
Elk[a]	49	8.3	29.2	10.4	18.8	4.2	8.3	2.1	18.8	95.9	4.1	0.0	2,739.7 (8,982.6)	106.2
Mule deer	23	8.7	26.1	4.3	21.7	8.7	17.4	0.0	13.0	100.0	0.0	0.0	2,773.3 (9,092.7)	106.9
Sheep	29	10.3	13.8	0.0	20.7	10.3	13.8	0.0	31.0	89.7	10.3	0.0	2,728.8 (8,946.8)	123.2
No animals	10	0.0	50.0	20.0	10.0	0.0	0.0	0.0	20.0	100.0	0.0	0.0	2,683.7 (8,799.0)	194.8
Total[b]	90	6.7	27.0	7.9	19.1	5.6	9.0	1.1	23.6	90.0	10.0	0.0	2,731.0 (8,954.1)	122.9

[a] Sample sizes for elk use at salting locations: aspect (n = 48); slope (n = 49); and elevation (n = 49).
[b] Sample sizes for total salting locations: aspect (n = 89); slope (n = 90); and elevation (n = 90).

with these natural mineral locations, the overall and perhaps relative importance of these natural mineral sources to the Willow Creek elk population can be appreciated.

Besides providing big game with mineral supplements, licks also may serve as centers of social interaction (Robinson and Bolen 1989). Dalke and others (1965) showed salt blocks were preferred by both elk and deer over salt-impregnated soil. Dominant animals were found to ingest salt blocks, while subordinate animals competed for salty soil. This type of behavior was observed on two occasions in spring 1994, when groups of cow elk with their calves from the previous year were at salt placements. On 24 May 1994, a group of five of 11 elk were ingesting soil at a salting location adjacent to the Racetrack Corral (map 2). A collared cow and another mature elk bit the rear end of a yearling elk in an apparent attempt to drive this subordinate elk out of the group of elk eating salted soil. On 31 May 1994, two cow elk were ingesting soil under and near a salting log with two immature bull elk (presumably 1993 calves) in Ice Spring Canyon (fig. 2). The cows flailed these bulls on the side with their hooves and bit the bulls on the back in an attempt to drive them away from the salt. Classification of this salt placement revealed elk hair lying on the ground next to the salt log, impressions of elk teeth in the salting log, and evidence of elk chewing the wood to obtain salt.

The most impressive display of elk using salting locations occurred in the evening of 5 July 1994, as 162 elk were congregated around human-created salt licks adjacent to the pond (commonly referred to as Indian Springs) in the NE ¼, NE ¼ of Section 25 in unit 2 of the Davis allotment (map 2). Elk were observed here to engage in a variety of behaviors including ingesting soil, eating salt, drinking water, sparring, grazing, and chewing on salt sacks. Interestingly, a sheepherders camp was only 144 m from these elk.

Dalke and others (1965) found that salt grounds placed in areas of succulent herbaceous vegetation were used considerably more than licks placed in shrubby areas. The destruction of surrounding vegetation by utilization and trampling was associated primarily with the dispersion of salt blocks and the number of elk occupying the area. Continual replenishment of salt increased the intensity of destruction of the vegetation and increased soil erosion. Dalke and others reported that habitat destruction occurring in the immediate vicinity of salt blocks was inevitable.

Because herders placed salt in proximity to grazing sheep, an understanding of the correlations of environmental variables associated with sheep feeding sites with the distance to the nearest salt placement less than or equal to 1,000 m from those feeding sites revealed many interesting aspects of salting practices and animal use in the drainage. For instance, the distance from a sheep feeding site in summer and fall to a salt lick was significant and positively correlated to the distance to a source of water ($r = 0.46$, $P < 0.05$) and to a road ($r = 0.46$, $P < 0.05$) (table 24). Often, roads lead to water developments, and often salt is placed near these easily accessed watering points. Results indicate that 36.7 percent of salt licks were located less than or equal to 403 m (mean = 592.6 m, SD = 442.4) from a source of water. The mean distance of a salt or natural mineral lick (closest distance to either recorded, but generally a salt lick) from sampled stock ponds was 107.3 m (SD = 194.8) (appendix D, table D3).

To improve the distribution of cattle grazing, Vallentine and others (1984) recommended that salt be placed methodically over the range, not less than 0.54 km (0.33 mile) from water on grazing units of one section or more in size or less than 0.32 km (0.20 mile) in smaller units. Annual sheep and goat allotment operating plans prepared by the Uinta National Forest (S. Smith 1993, 1994, personal communication) often request salting locations not be placed near or no closer than 403 m (0.25 mile) from water sources. Salting locations close to water appear on map 2 and indicate a proliferation of salt placements close to the creek in Racetrack Canyon. In addition, most salt licks were close to stock ponds in the Beaver Creek allotment.

Salt licks used by sheep were positioned an average distance of 69.9 m (SD = 104.7) from a ridgetop, which was farther than salt licks used by elk (mean = 49.8 m, SD = 101.5) and mule deer (mean = 24.7 m, SD = 35.6) from a ridgetop (appendix D, table D2). The average distance of a salt or natural mineral lick (closest distance to either recorded, but generally a salt lick) from sampled sheep bed grounds was 33.7 m (SD = 31.7) (appendix D, table D3). The occurrence of salting areas adjacent to sheep bed grounds and watering facilities may cause sheep or elk herds to congregate at such areas. This may result in overgrazing ridgetops and slopes and riparian areas as detailed in the Uinta National Forest's *Rangeland Ecosystem Forest Plan Amendment* (U.S. Forest Service 1993).

A problem with salt placements occurred in spring 1994 as elk would leave forested areas on the north side of Racetrack Canyon at night and cross the stream to ingest soil from salt placed on four rocks the previous fall (1993) an average of 20.5 m (SD = 5.1) west of the stream. By 29 June 1994, hoof action of elk had worn down the bank adjacent to these rocks sufficiently to uproot grasses and denude a section of the stream bank. Later in the season, saw groundsel (*Senecio serra*), a forb avoided by elk and sheep (appendix A, tables A5 through A7), invaded this site, replacing the soil-binding roots of grasses, and therefore perpetuating bank instability at this site.

Irwin and Peek (1983) found that preferred habitat by northern Idaho elk in spring contained salt licks that were used primarily in spring and that initiation of vegetative growth was early in these areas. A similar area in the Willow Creek study area where salt licks were available in conjunction with early spring vegetative growth was on the southern exposures of Buffalo Canyon in the Davis (unit 1) and Center Canyon (unit 1) allotments. Maps 1 and 2 confirm locations of salting placements and ground and aerial elk locations in spring 1993 and 1994. These were some of the first areas where elk entered in the spring. Incidentally, the two cow elk at elk feeding site 1 in 1994 (map 2) were 18 m from a sheep salt lick. Skovlin (1982) concurred that the amount of salt ingested by elk was related to seasonal forage succulence and phenology. In Skovlin's study, 50 to 75 elk consumed an excess of 22.7 kg (50 lb) of coarse granulated and dyed salt at four troughs placed in a 200 ha (494 acre) study area in the Blue Mountains of Oregon in June 1973. This herd ingested an average of 5.0 kg (11 lb) in July, 0.9 kg (2 lb) in August, 0.4 kg (1 lb) in September, and 2.7 kg (6 lb) in October (October salt ingestion increased over September due to fall green-up caused by autumn rains) at the four salting stations.

The distance (m) to salt was a selected independent variable in regression analyses of feeding site selection only for sheep. Distance to salt and the grams of herbaceous biomass at sheep feeding sites in summer and fall were the only variables that contributed significantly ($P < 0.05$) to this regression (table 22). Domestic sheep or their herders or both selected sites that were high in standing herbaceous biomass and close to salt. Because elk return to these areas to obtain salt in spring and summer, their foraging must be relegated to some extent to areas of high herbaceous biomass near salt placements. Consequently, the amount of herbaceous biomass at elk feeding sites was selected as a variable important in regressions of feeding site selection in spring, and in summer and fall combined (table 22). In conclusion, it appears that ample herbaceous vegetation was generally found near areas with salt licks, and these areas induced elk and sheep to feed, particularly in spring and summer.

Natural Mineral Lick Analyses

Concern was initially expressed from the U.S. Forest Service pertaining to soil and vegetation damage due to elk concentrating on seeps in the NE ¼ of the NW ¼ of Section 28 in unit 1 of the McKinney allotment (Racetrack Hollow) and in the NE ¼ of the SE ¼ of Section 16 in unit 1 of the Center Canyon allotment (Buffalo Canyon) (map 2). In 1993, elk at the Buffalo Canyon seeps were observed to drink water and ingest soil dug out with their hoofs. Elk were using these sites as sources for minerals. The following locations (map 2) were identified as natural mineral licks in the study area: two springs in Buffalo Canyon; one seep located in the Racetrack Hollow exclosure; one spring due north of the Racetrack Hollow exclosure seep (first noticed and observed to be used by elk in 1994); two seeps due west of the Racetrack Hollow exclosure; one seep in Section 32 of unit 1 of the McKinney allotment (Ice Spring Canyon); one spring in Section 28 in Willow Creek Canyon; and one piped spring with water flowing into a trough in Section 11 in French Hollow.

Elk were observed on several occasions to drink water and dig and eat soil from the two Buffalo Canyon seeps in 1993 and 1994; elk were seen on and near the Racetrack Hollow exclosure spring in 1993 and 1994; elk were startled as they were coming to the French Hollow Spring in 1994; deer tracks were observed at the Willow Creek Canyon spring in 1994; elk tracks were observed crossing the two seeps west of the Racetrack Hollow exclosure seep in 1994; elk tracks were observed at the newly formed spring in Racetrack Canyon in 1994; and elk were observed at the seep in Ice Spring Canyon in 1994.

Robinson and Bolen (1989:237) referred to licks as "natural formations of mineral-bearing soils, sometimes associated with saline springs." Carbyn (1975) characterized mineral licks as bare areas (either depressions or elevations) at which constant use by ungulates keeps the area exposed. Vallentine (1989) referenced Hamilton and Jepson (1940) to define springs as generally emerging from hillsides with a downward or horizontal inflow. Cowan and Brink (1949) distinguished between wet and dry earth licks. Wet licks are either mineral springs or muck licks. Licks are muck licks when soils in flatter areas are saturated by water.

Based on this classification scheme, the mineral seep adjacent to the stream in Ice Spring Canyon and the three mineral seeps along the stream in Racetrack Hollow could be considered muck licks (map 2). Most of the soil around the lick in the Racetrack Hollow exclosure was dry and contained 35.9 percent organic matter (table 20). A perched seep was the source of this mineral source and after forming a small marsh at its origin was diverted under the dry soil and into Racetrack Creek. The other five (55.6 percent) licks were located at the origin of springs, and therefore could be considered dry licks (map 2). Water from the Buffalo Canyon mineral springs flowed into the creek in Buffalo Canyon (map 2). Similarly, Holl and Bleich (1987) reported that 13 of 15 licks found in their study of desert bighorn sheep (*Ovis canadensis mexicana*) use of mineral licks in Southern California were seeps, one was a lick immediately adjacent to a river, and one was a solid rock lick. By comparison, Dalke and others (1965) found that all but two of 22 natural licks in two drainages were adjacent to a creek.

The concentrated hoof action of ungulates congregating around mineral licks can cause tremendous impacts on adjacent vegetation and soils. Calef and Lortie (1975) reported that an area 23 m in diameter around a mineral lick had been denuded of vegetation and packed hard by barren-ground caribou (*Rangifer tarandus granti*) of the Porcupine herd on the Yukon Arctic Coastal Plain. Trails worn in the tundra vegetation accessed the lick from several directions. Knight and Mudge (1967) described a mineral lick used by mule deer and elk predominantly in spring and fall in the Sun River drainage of the Lewis and Clark National Forest in the western part of the Sawtooth Range, MT. This lick measured 61 m (200 ft) long, 45.8 m (150 ft) wide, and 10.7 m (35 ft) deep, and an estimated 28,000 m^3 (1,050,000 ft^3) of geological materials had been removed by trampling-induced erosion and consumption by animals. Weeks (1978) reported that the largest lick used by white-tailed deer on a munitions depot in southern Indiana was 15 x 7 m and was 0.5 m deep.

Mineral licks in Buffalo Canyon and Racetrack Hollow showed the greatest use by elk. At the Buffalo Canyon mineral seeps (map 2), high ungulate use has resulted in numerous trails, erosion, and the formation of a weedy plant community. This weedy community consisted of dense stands of unpalatable plant species including saw groundsel and stinging nettle (appendix A, table A6). Elk feeding site 20 in 1993 was located here (map 1) and was the only instance in which cheatgrass (*Bromus tectorum*) was found at a feeding site (Beck 1996). The mineral seep in Racetrack Hollow is adjacent to the creek. Due to the dry nature of soil at this lick, and its proximity to the stream, much bank damage has occurred and little vegetation remains on the bank. In 1994, some vegetation was observed to establish itself inside the exclosure, but elk use around the perimeter of the exclosure appeared to begin enlarging the denuded area.

Kindel (1958), Knight and Mudge (1967), and Robinson and Bolen (1989) reported that in addition to providing big game with mineral supplements, licks may also function as habit-acquired social centers. Carbyn (1975) suggested that some animals come to licks not because of a physiological need, but to remain in a herd. Knight and Mudge observed that usually only one or two animals used a lick while many animals at licks apparently showed no interest in the lick, and lick-centered social habits could only develop after establishment of a lick. By comparison, elk in all sex and age categories observed at the Buffalo Canyon mineral licks were observed to be engaged in a variety of behaviors (for example, calves sparring, cows nursing calves, and bulls grazing) while as many as several elk at any given time would actually be drinking water or ingesting soil at mineral springs.

In the Ballinger Creek region of their study area, Dalke and others (1965) found elk preferred natural licks to artificial salt grounds established in the same vicinity. Natural licks received elk use similar to artificial licks in the area with as many as 200 elk congregated on these mineral licks in a single day from mid-May to mid-June. Elk use of these sites as well as artificial licks essentially ceased by early August. Similarly, the Buffalo Canyon springs and surrounding areas received elk use with a high count in 1993 of 71 elk observed at these licks on 17 August (map 1) and in 1994, 90 elk were observed at the Buffalo Canyon licks on 29 June (map 2). After being startled by an observer on 30 August 1994, 111 elk classified near Ice Spring initially moved to and congregated around the mineral seep east of Ice Spring (map 2) before returning to cover. High numbers of elk (estimated at more than or equal to 100) were observed and startled in the late evening near the Racetrack mineral seeps on 14 and 15 July 1993 (map 1). On 6 June 1994, nine elk (three yearling bulls and six mature cows) were observed grazing inside and adjacent to the Racetrack seep exclosure (map 2) and elk feeding site 15 was established at that time. Use of standing herbaceous biomass at this feeding site was 1.0 percent (table 14). This seems to indicate that the main elk activity at this location was mineral ingestion, not foraging.

Watts and Shemnitz (1985) concluded that peak mineral lick use in North America generally occurs during spring, coincident with an increase in vegetation emergence and green forage availability. Geist (1982:229) implied that elk should use mineral licks in spring during “the time of great hair, antler, and body growth, much as do sheep and mountain goats.” In California, bighorn sheep used natural mineral licks from April to September, and lick use was significantly correlated with the water content in browse (Holl and Bleich 1987). Excretion of significantly higher levels of fecal sodium occurred in white-tailed deer (Weeks and Kirkpatrick 1976) and mountain goats (Herbert and Cowan 1971) as they fed on succulent, new-growth forage. These occurrences indicate the need for ungulates to replenish supplies of minerals in spring due to ingesting high levels of forage-derived water, which essentially “flush” minerals from their bodies. Consequently, the largest herds of elk observed at natural mineral licks in Willow Creek were in June when forage succulence was greatest (maps 1 and 2, appendix B, table B2).

Ranchers in the study area have observed that upon entering the area in the summer they can locate the previous year’s salt locations because elk remove the vegetation surrounding them in the spring (S. Aagard 1994, personal communication). Data indicate that elk concentrate on natural and artificial licks in spring and early summer (maps 1 and 2), thus concentrating grazing and trampling around these licks. Nearly all elk activity at the point of greatest plant succulence (spring and early summer) occurred on the west side of the drainage where all nine of the identified mineral licks occur (maps 1 and 2). All six identified elk dry-wallows occurred on the west side of the drainage near natural mineral licks (map 2). For example, three dry-wallows lying in Sections 15 and 16 to the north and northeast of the Buffalo Canyon seeps were an average of 537.3 m (SD = 67.8) from these natural licks (map 2). Additional elk activity associated with these mineral springs was evidenced by many elk antler scrapes close to the two mineral springs in Buffalo Canyon.

The slope at four licks was greater than or equal to 26° (table 26) and all of these were at the mouth of springs. In conjunction with the concentrated impact of ungulate hoofs, licks on these steep slopes are more likely to erode. The Buffalo Canyon mineral springs show this type of erosion, and the mineral spring in Racetrack Hollow began to show signs of this type of erosion in summer 1994. The only mineral lick at the mouth of a spring not greater than or equal to 26° was in French Hollow (map 2) and the slope here was 22°. This mineral spring was on a northwest aspect and was the only mineral spring not on a south-facing slope (table 26). Elk feeding site 32 on 12 September 1994 was 752 m from this mineral lick. This mineral lick was likely to be used in fall based on its position in relation to aspect, distance from roads, and the retarded plant phenology occurring here at this time of year (table 8, appendix D, table D1, and Beck 1996).

Jones and Hanson (1985) noted that three factors of soil chemical and physical testing seem to be most important in relating elk geophagic use to specific sites: (1) levels of important chemicals, minerals (especially alkaline-earth elements) and salts; (2) organic matter content; and (3) physical properties of each soil sample, including texture, odor, Munsell color scheme, and clay mineralogy. The Brigham Young University Soil and Plant Analysis Laboratory was given nine labeled samples for testing from the Willow Creek drainage. Some tests were performed with a water (H_2O) extract and some with an acetate (NH_4OAC) extract (table 20).

Dalke and others (1965), Knight and Mudge (1967), Herbert and Cowan (1971), and Weeks (1978) found that sodium was the element attracting game to the natural licks they studied. Data from this study (Willow Creek) indicate that sodium was usually the least plentiful element, and that the water-extracted sodium content ranged from 1.0 to 39.0 ppm in Willow Creek mineral sources with the highest level of water-extracted sodium at the only lick used exclusively by mule deer (table 20). High use by elk (appendix D, table D2) of abundant and well distributed (map 2) artificial licks supplied with salt composed almost entirely of NaCl (table 21) indicate that elk used natural mineral licks in the Willow Creek study area as a source of macro or micro minerals other than sodium.

Analyses of minerals in soils from the Willow Creek drainage seemed to agree with those of Jones and Hanson (1985). They compared the soil composition of 10 mineral licks used exclusively by elk: six licks in Wyoming, two in Alberta, and one each in Manitoba and British Columbia. Through comparing the grand means for all 10 of these licks, Jones and Hanson (1985:114) found licks used by elk "tended to be higher in calcium and lower in water extractable sulfate and chloride and in total sulphur." Percent calcium carbonate ($CaCO_3$) was 12.5 in the seep east of Ice Spring; 11.3 in the east Buffalo Spring; 11.6 in the west Buffalo Spring; 25.0 in the Racetrack exclosure seep; 27.2 in the seep west of the Racetrack exclosure; and 34.2 in the seep west of this previously mentioned seep (table 20). A correlation may exist between the use of the seeps in Racetrack Hollow and the high concentration of $CaCO_3$ (25.0 percent) present in the soil. The soil salinity level ($EC \times 10^3$) was second highest (2.1) at the Racetrack exclosure spring (table 20).

Grass tetany (hypomagnesemia, or magnesium tetany) is associated with lush growth in cool-season grasses and is characterized by low blood serum magnesium concentrations. This results from a simple magnesium deficiency in the diet or more often from reduced availability of and absorption of forage magnesium due to conversion in the digestive system to an insoluble form (Vallentine 1990). Robbins (1993) indicated that magnesium deficiencies in wildlife have

Table 26—Percents of aspect and slope and mean elevation (m, ft in parentheses) of locations of elk dry-wallows, natural mineral licks, stock ponds, domestic sheep bed grounds, and stock watering troughs in the Willow Creek drainage.

	Aspect								Degree of slope			Elevation (m)	
Feature	N	NE	E	SE	S	SW	W	NW	0-10	11-25	≥26	Mean	SD
Elk dry-wallow	0.0	0.0	0.0	16.7	0.0	50.0	16.7	16.7	0.0	83.3	16.7	2,744.1 (8,997.2)	45.4
Mineral licks	0.0	0.0	0.0	37.5	0.0	50.0	0.0	12.5	37.5	0.0	62.5	2,592.1 (8,498.8)	36.8
Ponds	22.2	11.1	0.0	33.3	22.2	0.0	0.0	11.1	88.9	11.1	0.0	2,727.9 (8,944.0)	95.8
Sheep beds	0.0	0.0	0.0	0.0	0.0	0.0	33.3	66.7	100.0	0.0	0.0	2,834.0 (9,291.7)	104.2
Water troughs	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	2,647.4 (8,680.0)	0.0

been extremely uncommon. However, such a deficiency was reported in tame deer grazing on a heavily fertilized pasture at Washington State University. Hyvarinen and others (1977) reported that grass tetany may have been an important contributing factor to mortality of emaciated reindeer consuming early spring forage in Finland. This condition was related to low blood serum calcium and magnesium levels. Prior to death, many afflicted reindeer suffered convulsions. Convulsions are characteristic symptoms of grass tetany (Hyvarinen and others 1977). Robbins (1993) referenced several authors and indicated that dietary factors such as high nitrogen, potassium, aluminum, long-chain fatty acids, or organic acids may affect absorption or use of magnesium, even when forage concentrations are high. Thus, in spring, when forage conditions are optimal, elk may be susceptible to this condition. This might be especially true following harsh winters because elk may be physically impoverished.

The National Research Council (1985:14) suggested "minimum recommended requirements of magnesium to be 0.12, 0.15, and 0.18 percent of dry matter for growing lambs, for ewes in late pregnancy, and for ewes in early lactation, respectively." Kincaid (1988) reported that the Council's magnesium requirements for most classes of livestock ranged from 0.07 to 0.20 percent. The fraction of magnesium in granulated salt at salt placements ranged from 0.06 to 0.18 percent (table 21). At these magnesium levels, domestic sheep and elk would have to consume extraordinary and toxic levels of human-placed salt to satisfy magnesium nutritional requirements. This level indicates that elk are probably not using this salt for magnesium, and greater sources of magnesium may be preferred especially as levels of magnesium in animals are suppressed during spring grazing. Percent magnesium in forage in the study area ranged from 0.05 to 0.45 percent. Magnesium was typically the lowest mineral fraction among macronutrients (calcium, magnesium, phosphorous, potassium, and sodium) analyzed in forages (appendix B, table B1). Thus, mixtures of plants found in elk and sheep diets in Willow Creek may not contain adequate concentrations of Mg. Both the salt mixture and forage consumed by elk and sheep in the study area may contribute to a lack of magnesium in elk and sheep diets.

The high elk use of both seeps in Buffalo Canyon relative to other mineral sources is apparently best correlated with a higher concentration of magnesium. The East Buffalo seep had 810.00 ppm magnesium and the West Buffalo seep had 800.00 ppm magnesium. These concentrations were the third and fourth highest, respectively. Overall, the Racetrack Hollow exclosure seep had the highest levels of acetate extracted magnesium (1,720.00 ppm), total sulfate sulphur ($SO_4 - S$) (36,550.0 ppm), acetate-extracted calcium (14,120.0 ppm), and acetate-extracted sodium (56.20 ppm) (table 20).

Vallentine (1990) related that high dietary concentrations of potassium decrease the availability of magnesium in spring forages, thereby increasing cattle susceptibility to grass tetany, and low dietary calcium levels also reportedly contribute to the outbreak of grass tetany. The percent calcium and potassium in granulated salt put out for sheep in the area was low (table 21) and were more moderate in Willow Creek forage with potassium usually higher than calcium (appendix B, table B1). Due to high concentrations of calcium in natural mineral licks in the study area (table 20), elk may alleviate deficiencies by ingesting soil or water from any of these mineral sources.

Zoopharmcognosy is the study of how animals use natural medicines derived from plants, other animals, soils, and other natural products. Dalke and others (1965) cited reasons for big game salting reported by Jones (1922) and Thomas (1926) and indicated that the placement of sulphurized salt could be used by big game to reduce mange and ticks. Synthesis of sulphur-containing amino acids (methionine, cystine, and cysteine) produced in the rumen requires an inorganic source of sulphur (Church and Pond 1988). High levels of sulfate sulphur at the Racetrack Hollow exclosure seep (table 20) may explain, through zoopharmcognosy, one reason that elk used this and surrounding seeps.

According to Darling (1937), wallowing by red deer in spring is thought to have a relieving function against dermal parasites. Darling also reported wallowing assists in removing old hair, while wallowing in peat may have a tonic effect on red deer skin. As a comparison, peat has long been used as an ingredient in soaps and ointments used to relieve human skin conditions. In addition, the mudded coat protects red deer against biting and blood-sucking insects (Darling 1937). Soils at the seep in the Racetrack Hollow exclosure contained 35.9 percent organic matter, which was the highest level of any mineral lick (table 20). Soils at this location are the only ones meeting requirements for organic soils (at least 30 percent organic matter) (Brady 1990). This approaches the definition of more than 50 percent organic matter in organic soils required to be a peat soil (Brady 1990). Although elk were never observed to wallow in natural mineral seeps in the study area, zoopharmcognosical wallowing in these mineral seeps would impregnate the pelage of elk with medicinal dust that could effectively kill or repel arthropods and Tabanid flies.

Fraser and others (1980) studied white-tailed deer and moose behavior at licks in Ontario where they also analyzed soil and water samples. They found three observations on the behavior of these cervids at licks that caused them to analyze mineral licks differently than in other studies: (1) both moose and deer drank copious amounts of water in the licks, but only at times they ate soil and vegetation in the surrounding area; (2) almost all drinking occurred where mineral spring water was known or believed to seep into the lick; and (3) moose and deer frequently urinated when using the licks. Fraser and others mentioned that experienced animals generally walked directly to the source of spring water upon entering licks, and this led them to determine that most of the water that collected in the lick area was not used. Urine was deposited in licks in areas of undisturbed mud and standing pools but infrequently was deposited at the actual spring source. In light of these observations, Fraser and others (1980:624) felt that "(1) water samples from licks should be collected from the stream source; (2) contamination by animal urine must be avoided; and (3) 'control' samples from a nearby stream or lake should be collected." Electrical conductivity (indicating high ion activity) at three licks was greatest at the source of mineral springs and decreased outward in irregular patterns, and soil samples from lick and nonlick areas revealed some of the properties of the spring water but not as well as analyses of water.

In regards to the Fraser and others (1980) study, the recommendation is to test water samples directly from each mineral spring and seep in the study area and then from nearby water sources to compare differences. Fortunately, an attempt was made during all soil collections to collect saturated soil at the spring or seep source. The only time when this was not done was at the Ice Spring Canyon seep and the two seeps west of the Racetrack Hollow seep because no direct source for the seep was discernable. Fraser and others detailed a method to locate hidden spring or seep sources. Rust from metal (piping and a trough) at the mineral spring in French Hollow may have biased results of soil analyses here (map 2). Results of soil analyses appear to be most reliable at the Racetrack Hollow exclosure, the Racetrack Hollow spring, the spring in Willow Creek Canyon, and the two springs in Buffalo Canyon. The elements in greatest quantities at Willow Creek mineral licks are calcium, sulphur, and magnesium (table 20).

The natural mineral licks in Willow Creek have probably been used by resident ungulates for centuries. Based on all the studies, it appears certain that as long as elk are in the Willow Creek area they will rely on minerals from natural and artificial licks. This seems equally certain given the social function of licks. Vegetation and artificial sodium licks in the area do not provide an adequate source of minerals for elk in Willow Creek. As a result, elk are using natural mineral sources for macro and micro minerals (other than sodium) lacking in their diets because natural licks contain insufficient amounts of sodium during vegetation emergence (spring and fall). This seems apparent given that elk generally congregated in higher numbers around natural mineral licks in the area than around artificial licks.

Two matters of elk management in the area seem equally certain: (1) an increase in the numbers of elk in this area will result in greater impact to watershed resources and disclimax changes in plant communities surrounding natural lick areas; and (2) fencing elk out of mineral lick areas will deprive them of essential nutritional components, thus lowering the overall health of this herd. Through understanding the nutritional importance of natural licks to elk in the area as related to the deficiency of such minerals as calcium, magnesium, sulphur, and potassium, in salt placed for sheep, it is speculated that sheep in the area may be mineral deficient. This seems apparent because sheep obtain all their mineral supplements from granulated salt.

Elk Dry-Wallows, Stock Water Developments, Sheep Corrals, and Bed Grounds

Throughout the drainage, various resource points aid sheep producers in maintaining successful operations. Stock water ponds, troughs, sheep bed grounds, and corrals are examples. Significant natural areas used by elk include seeps, wallows, and patches of trees. As the season progressed in 1993, it became apparent that other resource points besides salting locations were influential in determining elk and sheep distributions in the study area. Nine stock ponds, one water trough, three sheep bed grounds, and six elk dry-wallows were located, classified, and designated by Universal Transverse Mercator coordinates and waypoints (maps 1 and 2). Data taken mirrored that of salt locations. However, the distance to the nearest salt or natural mineral lick was added, and in 1994, distance of elk to horizontal obscurity cover was included.

Elk wallows are usually associated with antler rubbing on small nearby trees by mature bull elk and are important for identifying high-use habitats by mature bulls (Skovlin 1982). These wallows are created in moist areas during the rut (Lyon and Ward 1982). The first elk wallow created in a dry area was identified in the SE ¼ of the SE ¼ of Section 29 in unit 1 of the McKinney allotment during hot, dry weather on 21 July 1994. None of these dry-wallows were encountered in 1993. Elk created wallows on dry substrates in Willow Creek that were always less than or equal to 1,000 m (mean = 487.7 m, SD = 104.4) from a source of water (appendix D, table D3). These sources of water were natural mineral licks in five (83.3 percent) of six instances (map 2). Antler rubbing was common adjacent to these areas. There was no evidence at dry-wallows that elk ingested soil, and because these wallows were not located at spring sources, this seems unlikely. All dry-wallows were under aspen cover, and all dry-wallows showed that concentrations of elk at these locations had removed vegetation and disturbed the soil. An elk herd in summer 1994 at the dry-wallow in Section 28 in Racetrack Hollow (map 2) was using the site as shade. All dry-wallows were close to a ridgetop (mean = 195.0 m, SD = 100.7) and horizontal cover (mean = 47.0 m, SD = 12.8), but were far from roads (mean = 461.2 m, SD = 398.4) (appendix D, table D3).

These data suggest that elk dry-wallows were established in areas away from human interference, and in microclimates less favorable to biting flies. By the appearance of soil at these locations, it seems elk may have been wallowing in dry soil to reduce harassment from biting flies. Similar but larger heavily trodden areas used by sheep occurred under aspen and conifer cover close to stock ponds in Section 24 of the Davis allotment (unit 1) and in Section 3 of the Pete's Knoll/Broad Hollow allotment (unit 1) (map 2). Sheep in unit 1 of the Davis allotment were mainly ruminating while seeking shade from the aspen canopy during the afternoon.

Small earthen dams have been created to entrap water at several locations in the study area (map 2). Many spring sources in the area have been piped into troughs (map 2). These facilities help to distribute grazing activities and are used by both wildlife and livestock. However, several problems occur at such sites. Often, salt has been placed for sheep on rocks and logs near stock water ponds and troughs (map 2). Ungulates (primarily sheep) have formed erosive trails leading to many of these water developments. By looking at natural and artificial water sources on map 2, it seems that ample free water is available to animals in Willow Creek proper, and any future proposed developments should be weighed on the basis of their contribution to causing animal concentrations and watershed damage.

Locations of corrals used to manage sheep in the area are identified on map 2. High use by sheep occurs at the corral in unit 1 of the McKinney allotment. Sheep in the Center Canyon and Trail Hollow allotments can be serviced through the corral in Trail Hollow. This does not always happen, especially in the case of Center Canyon sheep. Often, sheep from the Center Canyon allotment are trailed to the corral in Racetrack Hollow for handling. Guidelines should be included in each allotment management plan that specify which corrals are to be used for handling the sheep in each allotment. It appeared that there were adequate handling facilities distributed throughout the study area (map 2). Three proposed additional corral locations in units 1 and 2 of the Center Canyon allotment are identified on map 2. Construction of such corrals may not seem warranted, and it is suggested that the Trail Hollow corral be used at all times by Center Canyon sheep herds to alleviate pressure on the forage base in the McKinney allotment.

Sheep bed grounds are placed on ridgetops (appendix D, table D3). Essentially, all large ridges in Willow Creek are used at one time or another throughout the grazing season as sheep bed grounds. A guideline given for the use of these areas by the Uinta National Forest (U.S. Forest Service 1993:II-21), is to "bed sheep no more than twice on the same bed ground during the same grazing season." This guideline seemed basically ignored by herders. Following this guideline more closely should assist in meeting guidelines for the improvement of these ecologically sensitive ridgetops.

Some problems existing on sheep bed grounds are the disturbance of soil and the change in plant communities. For example, sticky rabbitbrush was a consistent component of the flora found at sheep bed grounds. Salt placed near analyzed sheep bed grounds was less than or equal to 100 m (mean = 33.7 m, SD = 31.7) from bed grounds, and thus, after sheep use ceased on these bed grounds, salt left behind or leached into the soil later attracted cervids to these sodium licks.

Maps and Geographic Information Systems Analyses

Maps were constructed on a 1:24,000 scale and include legends as well as grazing allotment names and boundaries. All maps were built from segments of the Strawberry SW, Strawberry SE, Tucker, and Soldier Summit 7.5-minute U.S. Geological Survey Quadrangles that lie within the Willow Creek drainage.

Map 1 (1993 only) details elk locations with herd sizes, elk feed sites, sheep locations, sheep feed sites, salting and mineral locations, biting fly indices accompanying sampled elk or sheep classification sites, Utah Division of Wildlife Resources aerial (Loran) elk locations, King-Hayne transect lines, agency (Utah Division of Wildlife Resources [DWR] and U.S. Forest Service) vegetation sampling transects, large and small grazing exclosures, and resource points such as sheep bed grounds and water ponds. Results from King-Hayne transect lines (Hayne 1949; King 1937) and biting fly indices in 1993 were not used in the final analyses and therefore only indicate work locations. Elk and sheep locations and feed sites, Utah Division of Wildlife Resources aerial Loran locations and biting fly indices appear by month of classification on map 1. This map was constructed with 40-foot contour intervals and includes all 194 waypoints collected through the course of summer and fall 1993, as well as additional, plotted, resource points. The cadastral map system (township, range, section) and Universal

Transverse Mercator lines in the background of this map are to aid in locations. Variations in types of roads, topography, and water courses can be visualized on this map in relation to all data points.

Map 2 displays waypoints collected at 160 locations during the 1994 field season. King-Hayne transect lines and agency vegetation cages were not included on this map because they were not analyzed in 1994. The biting fly index numbers corresponding to elk locations on this map are reported in table 9. The location of existing and abandoned corrals is also shown on map 2. Proposed road closures (explained in the section, "Management Recommendations") are displayed on map 2. Additional resource points such as water ponds, classified in 1994, also appear on this map.

Map 3 displays 1993 and 1994 elk (total number of elk per classification) and sheep locations and feed sites as well as Utah Division of Wildlife Resources aerial elk locations overlying the vegetation cover layer. This vegetative layer will aid the map reader in visualizing which vegetation types elk and sheep used as well as relative distances to cover and habitat edges. Gap vegetation data from LANDSAT satellite imagery were used for the vegetation layer (Scott and others 1993). Gap analysis attempts to identify "gaps in the representation of biodiversity in biodiversity management areas" (Scott and others 1993:7). These vegetative zones were obtained from the ERDAS (Gap) biodiversity analysis of the State of Utah. Pixels were 30 by 30 m, therefore, only vegetation patches 900 m^2 or larger appear on the map.

Spatial analyses of these data revealed aspen types comprised 47.7 percent of the Willow Creek study area (table 27). Some discrepancies were noticed upon comparison of the Gap data to the actual vegetation existing at analyzed sites as well as throughout the study area. Changes were made in conjunction with the Brigham Young University Geographic Information Systems Laboratory and are detailed as follows:

1. Due to the fact that little or no Gambel's oak (*Quercus gambelii*) was present in the study area, all oak was categorized as aspen. This was justified because both species are deciduous and much of the oak class occurred within or adjacent to the aspen class.
2. The mountain riparian class was found to be inaccurate. Gap incorrectly located most of this type on ridgetops. This class is defined as willow, cottonwood, and other deciduous species; therefore, the mountain riparian class was combined with the aspen class.
3. The location of the grassland and dry meadow categories did not characterize the dominating sagebrush and rabbitbrush overstories that exist in these areas. These classes were combined into the new mixed shrub/perennial grass class.
4. Little or none of the pinyon/juniper type existed in the study area. This category was combined with the mountain fir class. This action was not considered to be significant.
5. Because ponderosa pine (*Pinus ponderosa*) was not seen in the area, the ponderosa pine and ponderosa pine/mountain shrub class were added to the mountain fir class. Ponderosa pine could be easily confused with mountain fir on satellite imagery.

Table 27—Relative sizes of gap vegetation zones and their relative use[a] by elk and domestic sheep as indicated by percent of total locations for 1993[b] and 1994[b]. Numbers in parentheses are sample sizes.

				Percent			
Vegetation zone	Percent area	Area (km^2)	Area (acres)	1993 elk	1994 elk	1993 sheep	1994 sheep
Aspen	38.19	38.60	9,538.06	50.8 (33)	30.5 (18)	31.1 (9)	15.6 (5)
Mixed shrub/perennial grass	28.13	28.43	7,025.05	30.8 (20)	35.6 (21)	48.3 (14)	43.8 (14)
Mountain shrub	11.89	12.01	2,967.67	4.6 (3)	18.6 (11)	13.8 (4)	25.0 (8)
Mountain fir	7.72	7.81	1,929.85	4.6 (3)	1.7 (1)	3.4 (1)	
Aspen/conifer	6.55	6.62	1,635.80	6.2 (4)	5.1 (3)		6.3 (2)
Spruce/fir	2.03	2.05	506.56			3.4 (1)	3.0 (1)
Wet meadow	1.98	2.00	494.20	3.0 (2)	3.4 (2)		6.3 (2)
Sagebrush	1.27	1.28	316.29		3.4 (2)		
Spruce fir/mountain shrub	0.67	0.68	168.03				
Spruce fir/mountain fir	0.53	0.54	133.43				
Mountain mahogany	0.38	0.39	96.37				
Barren	0.38	0.38	93.90		1.7 (1)		
Mountain fir/mountain shrub	0.30	0.30	74.13				
Total	100.02	101.09	24,979.34	100.0 (65)	100.0 (59)	100.0 (29)	100.0 (32)
Total aspen types	47.74	45.22	11,173.86	57.0 (37)	35.6 (21)	31.1 (9)	21.9 (7)

[a] Some of the locations are not represented as they were located outside of the area bounded by the gap vegetation coverage.
[b] A few elk and sheep locations are missing on map 3.

Edwards and others (1995) reported an overall map accuracy of 75.3 percent for the vegetation classification and mapping provided by the Utah Gap analyses. For cover-types where the number of samples was 30 or more, accuracy ranged from a low of 50.6 percent for sagebrush/perennial grass to a high of 88.0 percent for oak. A mountain mahogany class dominated by curlleaf mountain mahogany (*Cercocarpus ledifolius*) was questionable as this species was never observed. A barren (ground) classification appears as patches of white on map 3. These are mainly shale-dominated slopes along Willow Creek and its tributaries. Some of these barren areas are sheep bed grounds.

Foraging Exclosures and Long-Term Vegetation Monitoring

Large fenced exclosures constructed to exclude foraging by sheep and elk were erected in 1993 in Buffalo Canyon and Racetrack Hollow by the U.S. Forest Service (map 2). A middle fence 2.4 to 2.7 m high forms the east fence of the big game and sheep exclosures and partitions each exclosure into a big game and sheep exclosure on the west and a sheep exclosure on the east. These exclosures were constructed for experimental reasons in an attempt to separate impacts of sheep and elk grazing, not to protect spring sources (D. Nelson 1995, personal communication). Long-term monitoring of these sites is to occur on permanent vegetation transects established in both of the total (all ungulates) exclosures, the sheep exclosure, and outside the exclosure where both domestic sheep and elk graze.

The Racetrack Hollow exclosure was positioned upon a perched spring, which was used as a natural mineral lick by elk (map 2 and table 20). The Racetrack exclosure is 44.8 m wide. The sheep exclosure measures 96.1 m long by 22.9 m wide by 1.0 m high. The big game and sheep exclosure is 61.0 m long by 22.9 m wide. The Buffalo Canyon exclosure was built in a heavily used riparian area. The Buffalo Canyon exclosure measures 45.8 m long by 91.0 m wide; this square area being divided into (2) 45.8 by 45.8 m squares. The east square with a 1.0 m high pole fence excludes sheep, but allows entrance to big game.

As initially agreed by the U.S. Forest Service and the Utah Division of Wildlife Resources, small wire cages, excluding ungulate herbivory, were placed in 24 locations representative of plant communities throughout the drainage. These cages were positioned in sets of two square and one pyramidal cage. The square cages measured 0.92 m long by 0.92 m wide by 0.61 m high. Each pyramidal cage measured 1.5 m long by 1.5 m wide by 1.4 m high. Their locations have been plotted onto maps 1 and 2 to assist any future agency monitoring or retrieval.

These small wire cages allowed researchers to establish herbaceous vegetative production without grazing. Upon agreement, the Utah Division of Wildlife Resources big game range crew led by K. Applegate in 1993 conducted this research. Methods used to obtain these data included clipping the protected vegetation at the end of the growing season, and clipping the residual plant matter in an adjacent unprotected plot of the same size. Plant biomass was then separated into forbs and grasses and grasslike plants, oven-dried, and weighed. Plant biomass production by plant community was expressed as the average amount of dry herbaceous biomass acquired from clipping studies in each community. The difference in weights between protected and nonprotected plots were divided by the total weight of the protected plot and multiplied by 100 to obtain utilization on a percent basis. Some cages were clipped at the end of June 1993 and before sheep were stocked on the range in early July to assess the impact of elk grazing on vegetative production. These data were collected and analyzed in 1993.

Data were so variable that confidence intervals revealed these data were unusable (K. Applegate 1994, personal communication). Other problems with the results from these cage studies include extrapolating production and utilization data on a 100.1 km^2 rangeland from 72 small cages and verifying use of plots outside of these cages by elk or sheep. Results obtained from feeding site methodology used in this study yielded substantial and accurate data on the seasonal use of standing biomass by elk and sheep. In 1993, the Heber Ranger District established permanent plots in each sheep allotment to monitor range trend on a long-term basis. The initial base line data taken in 1993 will be compared to future studies to assess vegetation trends in the respective allotments.

Cattle Trailing Permit

The cattle ranch that borders the Willow Creek study area to the north has a crossing permit, granted by the Spanish Fork Ranger District, to trail 300 cows for 2 days in mid-October up Willow Creek to Buffalo Canyon, west to Indian Creek then down Sheep Creek (M. Depietro 1993, personal communication). The exact date of this event in 1993 was after 15 October and before 28 October. The crossing date in 1994 was not known, but should have been similar to the 1993 crossing date. As a result, cattle utilization of riparian and associated uplands along Willow Creek and in Buffalo Canyon was not reflected in vegetation analyses. The level of impact of these cattle on the fragile riparian zones in the study area is not known. Careful evaluations of these impacts should be conducted to assess possible management changes. Trucking rather than trailing these cattle from their private land summer range is an alternative. Trailing cattle along upland slopes and ridgelines would avoid the Willow Creek riparian area, but providing water sources for these cattle would require prior planning.

Observations of Wildlife

Sixteen mammal species including carnivores, mustelids, cervids, rodents, and lagomorphs were observed to inhabit the drainage during 1993 and 1994 (table 28). Mule deer were common wild ungulates observed in the area. Deer numbers in 1993 were lower than usual due to low deer numbers in deer herd unit 27 (Diamond Fork), poor fawn production, and 70 percent fawn mortality on ranges during the 1992-1993 winter (Utah Division of Wildlife Resources 1994). As a result, deer were sparsely scattered throughout the drainage in 1993. In 1993, higher numbers of deer were observed in the northern and western regions of the study area. In 1994, mule deer were more commonly

Table 28—List of observations of vertebrate wildlife[a,b] in the Willow Creek study area, 1993 and 1994.

Species	Common name
Amphibians	
Ambystoma tigrinum	Tiger salamander
Birds	
Nightjars	
Chordeiles minor	Common nighthawk
Phalaenoptilus nuttallii	Common poorwill
Passerines	
Carpodacus cassinii	Cassin's finch
Ceryle alcyon	Belted kingfisher
Coccothraustes vespertinus	Evening grosbeak
Colaptes auratus	Northern flicker
Corvus corax	Common raven
Cyanocitta stelleri	Steller's jay
Dendroica coronata	Yellow-rumped warbler
Dendroica petechia	Yellow warbler
Empidonax/Contopus spp.	Flycatchers
Hirundo pyrrhonota	Cliff swallow
Junco hyemalis	Dark-eyed junco
Lanius ludovicianus	Loggerhead shrike
Molothrus ater	Brown-headed cowbird
Nucifraga columbiana	Clark's nutcracker
Parus gambeli	Mountain chickadee
Passerina amoena	Lazuli bunting
Picoides pubescens	Downy woodpecker
Picoides villosus	Hairy woodpecker
Pipilo chlorurus	Green-tailed towhee
Piranga ludoviciana	Western tanager
Selasphorus platycercus	Broad-tailed hummingbird
Sialia currucoides	Mountain bluebird
Sitta carolinensis	White-breasted nuthatch
Sphyrapicus nuchalis	Red-naped sapsucker
Tachycineta thalassina	Violet-green swallow
Troglodytes aedon	House wren
Turdus migratorius	American robin
Zonotrichia leucophrys	White-crowned sparrow
Raptors and vultures	
Accipter striatus	Sharp-shinned hawk
Aquila chrysaeotos	Golden eagle
Buteo jamaicensis	Red-tailed hawk
Buteo swainsoni	Swainson's hawk
Raptors and vultures	
Cathartes aura	Turkey vulture
Circus cyaneus	Northern harrier
Falco sparverius	American kestrel
Otus kennicottii	Western screech-owl
Upland game birds	
Bonasa umbellus	Ruffed grouse
Dendragapus obscurus	Blue grouse
Zenaida macroura	Mourning dove
Waterfowl and shorebirds	
Actitis macularia	Spotted sandpiper
Anas crecca	Green-winged teal
Anas platyrhynchos	Mallard
Charadrius vociferus	Killdeer
Gallinago gallinago	Common snipe
Grus canadensis	Sandhill crane
Fish	
Oncorhynchus clarki Pleuriticus	Colorado River cutthroat Trout
Mammals	
Carnivores and mustelids	
Canis latrans	Coyote
Felis concolor	Cougar
Felis rufus	Bobcat
Mustela frenata	Long-tailed weasel
Ursus americana	Black bear
Cervids	
Cervus elaphus	Elk
Odocoileus hemionus	Mule deer
Alces alces	Moose
Rodents and lagamorphs	
Castor canadensis	Beaver
Erethizon dorsatum	Porcupine
Lepus americanus	Snowshoe hare
Marmota flaviventris	Yellow-bellied marmot
Peromyscus maniculatus	Deer mouse
Spermophilus armatus	Uinta ground squirrel
Tamias quadrivattatus	Colorado chipmunk
Taxidea taxus	Badger

[a] Mammal nomenclature follows that of Zeveloff and Collett (1988).
[b] Bird nomenclature follows that of the National Geographic Society (1991).

observed throughout the study area. In 1993, the first fawn was found on 20 July in unit 1 of the Center Canyon allotment. The first fawn seen in 1994 was on 29 June in Ice Spring Canyon in unit 1 of the McKinney allotment. This fawn was 147 m from sheep at feeding site 1 in 1994 (map 2). This was the only time in both field seasons that mule deer were observed less than or equal to 1,000 m from domestic sheep (appendix D, table D1). Deer were recorded six (9.5 percent) times less than or equal to 1,000 m from classified elk herds in 1993. Five (8.3 percent) times in 1994 deer were observed to be less than or equal to 1,000 m from a classified elk herd (appendix D, table D1). Agonistic behaviors were never observed between elk and deer.

Elk numbers were greater than mule deer in the study area and their presence as well as that of the deer within the drainage was often dictated by biological requirements such as using calving grounds and salt or natural mineral licks. In 1993, eight elk calves were first observed in unit 1 of the McKinney allotment on 7 June. In 1994, the first calf elk observed was following an estimated 40 to 50 m behind a cow on 2 June in Ice Spring Canyon in unit 1 of the McKinney allotment. In 1993, two mature bull elk on 17 August and one mature bull elk on 18 August were the first observed bulls with polished antlers. In 1994, the first elk seen with antlers completely scraped was a four-point bull on 30 August 1994 with 110 other elk near Ice Spring in unit 1 of the McKinney allotment. One cow moose was observed and recorded on 28 June 1993 in the Beaver Creek allotment. She was in the Ashley National Forest, in unit 3 of this allotment, and within 200 m from a nursery herd of 34 elk (map 1).

Black bear (*Ursus americana*), coyote (*Canis latrans*), cougar (*Felis concolor*), and bobcat (*Felis rufus*) inhabit the drainage (table 28). Black bear scat was found at two locations in 1993. One bear implicated with sheep mortality was killed by Animal Damage Control personnel in 1993 in the Road Hollow allotment. Black bear tracks were observed in mud along Willow Creek in summer 1994, and a yearling black bear was seen on 29 July 1994, on the east side of the drainage. Two archery elk hunters reported seeing another yearling black bear at a water pond on the west side of the study area on 6 September 1994.

Cougar tracks were observed on two occasions in 1994. Coyotes were seen on several occasions. On two occasions coyotes were in sheep herds, one of these sightings was associated with predation on sheep. A bobcat was seen crossing the road at the head of French Hollow in unit 1 of the Broad Hollow allotment (fig. 2) on 8 July 1994.

Forty-seven avian species inhabited the drainage including raptors, vultures, nightjars, passerines, upland game birds, waterfowl, and shorebirds (table 28). Many mallard and green-wing teal broods were observed in beaver (*Castor canadensis*) ponds throughout the drainage during both summers. An amphibian, the tiger salamander (*Ambystoma tigrinum*), was often present in stock ponds throughout the drainage (table 28).

Of special note was the presence of native Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) within Willow Creek and its tributaries (table 28). Recent genetic tests by Shiozawa and Evans (1993) indicate that cutthroat trout in Willow Creek are polymorphic, with four separate haplotypes. Their data detected introgression of Yellowstone cutthroat trout in the Willow Creek population at approximately 7 percent. They also attributed an additional 3 percent of the population to be fish originated in the Bonneville Basin and entering the Colorado drainage through a stream capture event or by being transported by humans. Purity of the Colorado River cutthroat trout in Willow Creek was thus considered to be 90 percent.

Conclusions

According to Hofmann (1988), ruminants may be classified as one of three morphophysiological feeding types based on gastrointestinal adaptations and specializations to exploit forages. This classification assumes ruminant evolution paralleled plant evolution, with the digestive system of recently evolved ruminant species specialized to exploit grasses, and more archaic ruminants adapted to utilize less fibrous plant matter found in geologically older browse and forbs.

"Concentrate selectors" such as white-tailed deer and mule deer are adapted to ingest plants or plant parts rich in easily digestible and highly nutritious plant tissues and have limited capacity to digest cell wall material (material high in cellulose, hemicellulose, or lignin). Cattle (Bovidae) and domestic sheep (Bovidae) are geologically recent and are specialized morphologically to digest fibrous plant foods, although they can also cope with rapidly digestible cell contents. A heterogenous group, the "intermediate" or "mixed feeders" such as elk, show adaptations to the one or other extreme, with some species being highly variable and flexible in the face of compositional changes in the forage base through time and space. Thus, theoretically elk and domestic sheep are physically and physiologically quite capable of exploiting the same food sources at least during certain times of the year or within certain habitat types depending on changes in and availability of forages (Hofmann 1988; Janis 1976).

Alexander and others (1983) found, through fecal analyses, that the summer diets of domestic sheep in sagebrush-grass rangeland in southeastern Montana were 96 percent grasses and sedges; forbs were less than 1 percent of diets and shrubs less than 3 percent.

In this study, Kulcynski's similarity indices between sheep diets and available plants were 36 percent in June, 37 percent in July, and 40 percent in August. Spearman's rank correlation coefficients (r_s) for sheep diet preference indices and forage plants were –0.57 for June, –0.49 for July, and –0.52 for August. These negative correlation coefficients indicated that sheep were seeking plants that were not abundant on this range.

Foraging elk and sheep in the forb- and browse-dominated area of Willow Creek clearly demonstrated the ability to switch diets in response to seasonal and yearly forage availability. The slight increase in the graminoid fraction of elk diets in fall over summer is attributed to improved precipitation that permitted regrowth and subsequently improved grass quality (Nelson and Leege 1982; Vallentine 1990). Occasionally, but not often, a slight increase in crude protein content of grasses occurred in conjunction with fall regrowth following rains (appendix B, table B1). For example, crude protein in mountain brome in summer 1994 was 7.9 percent and in fall 1994 was 8.3 percent (appendix B, table B1). This increase in crude protein content would make these grasses more attractive to elk and sheep.

Differences in moisture conditions may account for the increase in graminoids in 1994 sheep diets versus 1993 sheep diets (fig. 10). According to the Natural Resources Conservation Service, Centralized Forecast System (R. Wilson 1994, personal communication), total precipitation for the 1993 water year (1 October 1992 to 30 September 1993) was 67.3 cm (26.5 inches) and for the 1994 water year (1 October 1993 to 30 September 1994) was 43.9 cm (17.3 inches) at the White River 1 SNOTEL site. There was an increase in seasonal standing biomass of graminoids and a relative decrease in forb standing biomass in Willow Creek plant communities from the wet year (1993) to the drier year (1994) (appendix C, table C2).

In comparing standing biomass present in Willow Creek plant communities between summer 1993 and summer 1994 in only two (20.0 percent) instances (snowberry-forb and snowberry-mixed brush) were there more graminoid standing biomass present in 1993 compared to 1994. Likewise, in 1994, in only five (50.0 percent) instances (aspen-forb, mixed brush-grass, sagebrush-grass, snowberry-grass, and sagebrush-mixed brush) were there more standing forb biomass present than in 1993 (appendix C, table C2). Thus, across the various communities in summer 1994, graminoids were the dominant herbaceous component of plant communities. The increased fraction of graminoids in sheep diets in 1994 reflects the fact that sheep grazing was concentrated on the more available graminoids during this dry year.

Cook and others (1948) reported that on the Cache National Forest in northern Utah, grass constituted 71 percent of produced vegetation and contributed 42 percent to sheep diets. Twenty-nine percent of available forage was forbs, and these were about 29 percent of sheep diets. Browse constituted the remaining 29 percent of sheep diets in this study. Sheep, being intermediate feeders, are capable of switching their diet to take advantage of the most available forage.

Although variation exists seasonally between forage classes, elk seemed to utilize fewer of the available plant species than sheep (table 12). This may indicate: (1) sheep had the ability to select a wider range of forages than elk; or (2) due to the effects of herding, sheep were forced to eat a wider range of plant species as more palatable species decreased quickly in patches being grazed by gregarious flocks of sheep. Of those plant species used in common by elk and sheep, an apparent trend was observed for sheep to consume more standing biomass (appendix A, table A3) and more plant individuals (appendix A, table A2) than elk. This may be related to the fact that elk were more mobile foragers than sheep, particularly because sheep were herded and not permitted to range freely. Thus, sheep spent more time on patches of forage and as a result had a more concentrated impact on the vegetation.

Overall, the single or combined vegetative utilization levels by elk and sheep never exceeded U.S. Forest Service (1993) allowable use guidelines for satisfactory or unsatisfactory condition on overgrazed ridgetops and open slopes, aspen ecosystems, uplands, and riparian ecosystems; however, forage use of some individual plant species exceeded these allowable use standards. For example, the percent of current growth use of shrubs allowable in aspen ecosystems (uplands, aspen, grassland, shrublands, and timber) is 60 percent on satisfactory condition range and 40 percent on unsatisfactory condition range (U.S. Forest Service 1993). Sheep use in a grass meadow community in fall 1994 revealed that use of the current annual growth of viscid rabbitbrush was 68.0 percent and of red elderberry was 83.0 percent (appendix C, table C3). Use of red elderberry current growth also exceeded Forest Service guidelines at an elk feeding site (previously used by sheep) and two other sheep feeding sites in fall, 1994 (appendix C, table C3).

The individual and combined impact that elk and sheep are exhibiting on plant species in the study area at times is great, but the overall use of vegetation is light. Through selective grazing pressure, current livestock and wildlife numbers are probably inducing plant communities into disclimax conditions. Future range trend studies conducted on permanent plots in each allotment by the U.S. Forest Service will help to assess the component species of such disclimaxes.

These data should not be used to justify increases in numbers of elk or sheep. Data indicate that elk and sheep are acquiring the majority of their seasonal forage from a rather small suite of species (appendix A, table A4). Increased stocking would decrease the abundance of these palatable forage species, and elk and sheep in the drainage would be required to subsist on less desirable species, some of which contain poisonous compounds (appendix B, table B3). Plant succession and community composition would invariably change, resulting in habitats less capable of supporting a variety of native wildlife species. An additional, evident, consequence of increased elk and sheep stocking rates in the area would be increased impact on soils in riparian zones. Rather than advocating increases in elk or sheep numbers, ways are recommended (in the section, Management Recommendations) to improve range conditions in the drainage to make current elk and sheep numbers more compatible with the natural ecosystem of the area.

Forage species making up a large portion of elk and domestic sheep dietary overlap could be designated as species that indicate rangeland health. Because these plants are subject to dual use by elk and sheep, they should be closely evaluated to safeguard against overuse. These management indicator species could then be monitored in study area allotments to assess range trends. When utilization, frequency, or cover of these species reach levels exceeding Forest Service guidelines, then corrective management measures could be undertaken to alleviate overuse and further decline of these plants. Currently, the Uinta National Forest lists selected plant species as indicators of proper vegetation conditions at range sites. Relative abundances of these plants are assessed by volume or community composition (U.S. Forest Service 1993).

Data from this study suggest that several plant species could be used by the Forest Service to monitor range conditions in the area. Those herbaceous species that comprised greater than or equal to 5 percent of sheep and elk diets during at least one season of 1 year were selected as indicator species. Browse species were selected according to this criterion. However, dietary incorporation of browse species was not always greater than or equal to 5 percent of elk and sheep diets during a given season (appendix A, table A4). Selected indicator plants generally had high Ivlev's electivity indices values (appendix A, tables A5 through A7). Viscid rabbitbrush was not selected as an indicator species because it is commonly considered to be a weedy shrub. Sheep, which mainly use this plant, may be beneficial in biologically controlling this species.

It is recommended that tall bluebell be designated as a forb indicator species. The delineation of tall bluebell as a management indicator species warrants consideration of the biology of this species. Due to the rhizomatous growth habit and relatively quick phenological changes of tall bluebell, it can increase under grazing pressure because it escapes heavy grazing (Matthews 1965). As such, this forb may even increase following years when heavy grazing occurs. Extreme or prolonged heavy grazing would cause this species to decrease and hence warrants it as a prime species to monitor as an indicator plant. Recommended grass indicator species are mountain brome, smooth brome, and slender wheatgrass. Browse species recommended as indicator species are red elderberry, aspen, mountain snowberry, and Wolf willow (*Salix wolfii*).

Natural mineral sources in the area are nutritionally important to elk and certainly add to the overall health of this productive herd. Elk use of sodium licks placed for sheep may represent a habit-formed luxury and probably exceeds the health requirement of elk. Granulated salt placed for sheep in the area was almost entirely sodium, and thus sheep may be somewhat mineral-deficient because they do not regularly visit natural mineral sources in the area.

Sheep movement patterns throughout the drainage appeared to be related mostly to human influence. On the other hand, elk distributions throughout the area were influenced by seasonal human and nonhuman factors. Human factors included how far elk were from roads in fall and the proximity of elk to sheep salting grounds in spring and summer. Nonhuman factors influencing elk distributions included cool or windy areas that were free of biting flies in summer and feeding sites that had high standing plant biomass in spring, summer, and fall. Because wild, free-ranging elk were compared to tame, herded sheep, it is not surprising that the unrestricted elk displayed more complex habitat relationships. In general, elk distanced themselves from sheep but stayed in the same general area to use salt placed for sheep.

Management Recommendations

The Utah Board of Elk Control, later to be known as the Board of Big Game Control, was established in 1925 to cope with deteriorating range conditions caused by an increasing elk population (Utah Division of Wildlife Resources 1994). Vallentine (1989) described range management as both an art and a science directing management of resources based on land ownership objectives and societal needs and directed traditionally at livestock and big game production. According to Mohler and Toweill (1982:561) wildlife management may be directed toward either or both of two production goals: (1) managing for optimal numbers of a rich species assemblage; or (2) managing for production of one or more featured species, even at the expense of other species (Thomas 1979). After an in-depth review of literature, Grumbine (1994:31) identified five specific goals of ecosystem management endorsed by ecological researchers: "(1) maintain viable populations of all native species in situ; (2) represent, within protected areas, all native ecosystem types across their natural range of variation; (3) maintain evolutionary and ecological processes (that is, disturbance regimes, hydrological processes, nutrient cycles, and so forth); (4) manage over periods of time long enough to maintain potential species and ecosystems; and (5) accommodate human use and occupancy within these constraints." Grumbine related that the first four of these goals are value statements derived from scientific knowledge aimed at eventually eliminating the loss of biodiversity. The fifth goal endorses the functional role that humans fill in the debate over ecosystem management.

Robinson and Bolen (1989) maintained that the carrying capacity for animals can change seasonally and yearly in relation to varying conditions including food production and availability of water and cover. The carrying capacity for ungulates using a rangeland should thus be managed for the season of fewest resources during the year of fewest resources to perpetuate sustainable foraging without causing damage to a diverse biological system. The season and year of least abundance in terms of elk and sheep in Willow Creek should be fall during drought years. A rich assemblage of identified or reported species in the Willow Creek area includes 188 vascular plant species, 47 avian species, 16 species of mammals, an amphibian, and a native trout species (appendix B, table B3; table 28). As a result, the need to protect biodiversity and other natural resources including a healthy watershed in this semiroadless area seems imperative.

Recommendations for management of the Willow Creek drainage based on scientific research are detailed in the remainder of this section.

Road Closures

Implementing proposed road closures in map 2 will assist in restoring watershed health and improve seasonal use conditions for elk in the area. Sheep may also benefit by being farther from human disturbances. Roads as a major influence on elk activity may be summed up in the findings of Edge and Marcum (1985) who concluded that elk moved significantly longer distances away from human-caused disturbance than toward disturbance. To maintain the integrity of the elk herd and particularly important calving areas, roads proposed for closure in the west and southwest areas of the drainage have been identified (map 2). These closures will assist elk by creating areas of little human disturbance. An additional benefit from closing roads may be realized through higher hunter success as more elk should remain longer in the area during the hunting seasons.

According to the 1988 Uinta National Forest Travel Map, "Motorized vehicles are not allowed to travel off of the roads and trails shown on the map" except for five reasons. One permitted reason to drive off of these roads and trails is to "...retrieve legally taken big game animals using a desirable direct route not disturbing the soil or vegetation." Hunters were often observed to abuse this rule and travel on closed roads during hunting seasons whether they had harvested game or not. The biological value of the Willow Creek drainage is great enough that regulations should be passed and vigorously enforced to limit vehicle use to main roads and prohibit off-road vehicles. The following list of roads to be considered for closure (including justifications for closure) is offered:

1. Reclosing roads in Center Canyon (unit 1), Road Hollow (unit 2), McKinney (unit 1), and Cabin Springs (unit 2, starting in Section 7) allotments seems necessary because vehicles (especially off-road vehicles) still use these roads.
2. Closure of the road accessing Willow Creek near the west end of Road Hollow, and the road in unit 1 of the McKinney allotment adjacent to the guard station (map 2), is urgent because people often drive down these roads to access Willow Creek and then drive off-road vehicles along and through Willow Creek. Fence barricades may need to be erected to stop all access to these roads.
3. The road proposed for closure in Section 10 of the Center Canyon allotment (unit 1) (map 2), which leads toward Buffalo Canyon, is deeply rutted. Sediments from this road are washed into Buffalo Canyon. This road runs north above the mineral licks used by elk in Buffalo Canyon (map 2). A good trail head exists to access Buffalo Canyon, and this closure appears extremely urgent for elk security and watershed stability. Closure of this road from its junction with the Stinking Springs Road should also be evaluated because this would essentially create a large roadless area predominating in the eastern portion of Buffalo Canyon. A foreseen problem may be higher elk concentrations in Buffalo Canyon due to the creation of a large area of undisturbed habitat close to natural mineral licks.
4. The road in the NW ¼ of the NW ¼ of Section 10 in unit 2 of the Center Canyon allotment leads to a previously closed road and appears to serve no purpose. Therefore, this road has been proposed for closure (map 2).
5. The road proposed for closure in unit 3 of the Ingram allotment serves no worthwhile purpose, and it appears that closing this road would serve to create a large roadless area in the southeast part of the drainage (map 2).

6. The road in Ice Spring Canyon is proposed for closure because elk concentrate in this area to calve and vehicles cause elk to move. Vehicles also cause much soil disturbance near the spring source in Ice Spring Canyon (map 2) and it was evident that some traveling occurs along the closed road past the spring.

7. A good road exists from Spanish Fork Canyon to Buffalo Canyon that is used to access Trail Hollow, Willow Creek Ridge, and the Left Fork of the White River (map 2). The road that extends from this road in Section 23 of the Davis allotment, unit 1, to near the ponds in Section 2 in unit 2 of the Davis allotment is essentially a shortcut route to access Willow Creek Ridge and the White River. Closing this road would create a large area of undisturbed habitat and further enhance the watershed by restricting vehicle travel to the graveled road in upper Buffalo Canyon.

8. The road proposed for closing that begins in Section 24 of unit 2 of the Road Hollow allotment and continues into unit 1 of the Cabin Springs allotment appears to serve no purpose. Closing this road would create a large area of undisturbed wildlife habitat and enhance watershed conditions.

9. A road proposed to be closed adjacent to the study area spans from Section 8 to Section 4 in the headwaters of Trail Hollow (map 2). This is a shortcut route from Trail Hollow to French Hollow. Due to the steepness of terrain in this area, this road most certainly should be closed to protect watershed health.

Aspen Regeneration

Jones and DeByle (1985) reported that fire was clearly responsible for the abundance of aspen in the West and almost all even-age aspen stands appear to be the result of severe fire, whether or not aspen types were climax on sites. Jones and DeByle indicated that evidence including dated fire scars and historical records suggest that before and during the mid-19th century, much larger acreages of aspen burned than have burned since. Baker (1925) and Meinecke (1929) found few aspens fire-scarred later than 1885 in the Ephraim Canyon area of central Utah. They reported that fire scars were common in aspen here earlier than 1885, indicating that fire burned here at 7 to 10 year intervals. Aspen forests are clearly dependent on fire regeneration to renew them, and fire suppression causes them to degenerate.

Currently, aspen stands in the West are aging (Mueggler 1989), and much of the western aspen acreage is dominated by pole (mature) and saw timber-sized (over mature) trees (Green and Setzer 1974). According to Greenway (1990:21): “An aspen grove will dominate an area until either (1) shade tolerant conifers reach a height sufficient to take over; (2) the aspen grow old and decadent, eventually leaving brush and grass; or (3) the aspen reestablishes itself after a natural catastrophic event, such as a fire, prevents succession from running its course (Shields 1981).” Jones and DeByle (1985) reported that sheep and cattle grazing annually removed fine fuels from aspen understories, which in turn reduced the flammability of aspen stands.

Lavertu and others (1994) related that opening the aspen canopy by disturbances such as prescribed burning and clear cutting could modify such factors as light and temperature that may enhance sucker production. Greenway (1990) explained that suckering is normally inhibited through apical dominance because auxin (a plant hormone) is translocated to the roots from growing shoots and leaves. Schier (1981, in Greenway 1990) related that disturbances that damage or kill stems will reduce the flow of auxin into the roots and thus stimulate aspen regeneration. Following prescribed burning of aspen on the Caribou National Forest in southeast Idaho, Brown and DeByle (1989) found that densities of aspen suckers regenerating aspen stands peaked in the first 2 postburn years and ranged from 0.5 to 5 times their preburn densities. Lavertu and others (1994) found that aspen sucker production was not related to stem density before clear cutting, but rather was related to the amount of litter whereby increasing litter cover lowered the production of suckers. DeByle (1976) mentioned that the impact of humans on western aspen habitats through fire suppression, maintaining levels of deer, elk, and moose near carrying capacity, and overgrazing by livestock have all contributed to lower aspen regeneration.

Most aspen stands in the Willow Creek study area are even-age and mature, or overmature, indicating that past fires initially influenced the creation of the aspen stands. This fact and results of the use of aspen reproduction in the Willow Creek study area demonstrate that historical sheep grazing coupled with more recent increases in elk populations are probably the most dominant influences currently controlling aspen stand regeneration. Greenway (1990) related where cattle and big game have access to aspen shoots, their browsing and trampling can convert these areas to sagebrush and grassland. Greenway recommended reducing or removing livestock for 5 to 10 years and controlling wildlife from local areas around aspen disturbances.

Elk, mule deer, and domestic sheep conceivably may be classified as the featured species (Thomas 1979) in the Willow Creek drainage. However, according to goals of ecosystem management (Grumbine 1994), viable populations of all native species should be the object of management. The effect of low aspen regeneration on wildlife species dependent on aspen thickets was indicated by no observations of ruffed grouse (*Bonasa umbellus*) broods and only one observation of a snowshoe hare (*Lepus americanus*) during the two field seasons. Areas near Willow Creek that were previously cut-over and later abandoned by beaver now support high numbers of aspen saplings. Clearly, the effect of beaver on aspen in the area shows that aspen in Willow Creek will produce suckers in response to disturbances. The overall health of this aspen ecosystem and its ability to support viable populations of all native species is now pitted to an extent against the ability of aspen stands to regenerate themselves.

Some methods of aspen regeneration would cause other foreseen problems. For example, most forms of timber harvest require extensive road developments (Lorimer 1990). A method such as prescribed burning is recommended to maintain the roadless nature of Willow Creek. An additional method could be anchor-chaining of aspen stands. Aspens knocked down by chaining could be winnowed in areas to restrict use by livestock and big game until debris had sufficiently decomposed. Theoretically, at this time aspen regeneration should be to a point where most stems would be large enough to escape destructive herbivory by elk and sheep. Chained logs could be piled onto roads proposed to be closed. These actions will circumvent erosion inherent from road construction in such a topographically steep area containing highly erodible soils.

An additional benefit of burning would be the elimination of disturbed sites, which are often sites of weed establishment. It is also recommended that areas prescribed to be burned are rested from sheep grazing during the year they are burned to allow for build up of flammable fuels. These same areas should be rested from sheep grazing for 5 to 10 years following burning and should be far enough away from cover (more than 300 m) to discourage significant use by wild cervids (Greenway 1990; Winn 1976). If these disturbed aspen sites are not large enough to discourage cervid use, they may effectively become centers of high foraging activity with abundant aspen suckers experiencing more browsing pressure than under undisturbed situations. This in effect could create a disclimax community lacking aspen. The following steps are offered according to these guidelines:

1. Select areas of good soil stability in each allotment where burning could be done and is necessary (according to stand age and current regeneration level).
2. Designate the McKinney allotment as a management allotment as it has been in the past (S. Smith 1995, personal communication) to facilitate holding sheep from allotments to be burned.
3. Allotments that are to receive prescribed burns may need to be transformed into rest-rotation grazing system units to keep sheep out of burned areas in the same allotment.
4. Select areas to be burned that are large enough and far enough (more than 300 m) from habitat edges (Winn 1976) to discourage over use by elk.
5. Restrict sheep grazing from these areas during the summer before the burn to allow for accumulation of flammable fuels. Information on aspen fuels and their flammability was compiled by Brown and Simmerman (1986).
6. Burn these areas in late September or early October after drying of the standing crop in the understory and in conjunction with aspen leaf fall and before fall snows to obtain the best burning conditions (Jones and DeByle 1985).
7. After burns, restrict sheep from grazing these areas for at least 5 years. This will require coordination and frequent checks on sheep band locations.

Riparian Habitat Restoration

Several range management methods have been mentioned to help restore riparian habitats in the study area. One is to keep salting locations greater than or equal to 403 m (0.25 mile) away from watering sources. After careful evaluation, another management recommendation may be to curtail the trailing of 300 head of cattle from a cattle ranch up (southwest) Willow Creek and Buffalo Canyon. By keeping populations of elk and sheep in check in the study area, riparian damage should not escalate. The integrity of this watershed is important in providing quality habitat for the nearly native Colorado River cutthroat trout population that resides in the Willow Creek drainage.

Weed Control and Maintenance of Native Plant Communities

Spraying and hand-weeding of musk thistle (*Carduus nutans*) by crews assigned or contracted by the U.S. Forest Service was observed along roads in the area during the field work period. Because weeds readily colonize disturbed sites, the restriction of any new road building would limit new locations in the area as additional sites for weed establishment. Most plant species in the study area are native. Management efforts to maintain them should be exercised. Areas in the drainage where meadow fescue and smooth brome have been seeded are now dominated by these two exotic grasses. Although smooth brome in particular provides large amounts of high quality forage for sheep and elk, it out competes native plant species in patches of sagebrush and perennial grasses. It is recommended that native seed mixes be used when needed to perpetuate the native flora.

Sheep Salt Supplements

To control the effect of hoof impaction on sensitive soils near sources of water and on ridgetops, a regulation should be enforced requiring all salt placed for sheep to be greater than or equal to 403 m (0.25 mile) away from any water or ridgetop. With no new salt added to improperly placed licks, sheep, elk, and deer will gradually lose interest in these sites and they could be naturally revegetated. Many old licks in the drainage have gone through this process.

An additional practice could be implemented where salt is placed at the same location for no more than one grazing season. This would help alleviate accumulations of salt in the soil and would probably assist in reducing habitual wild ungulate impacts around salt logs and rocks. However, it is difficult to assess whether this would promote numerous disturbed sites throughout each allotment. The application of this method seems to be too rigid for normal livestock operating situations.

Stock Water Developments

Previous construction of stock watering facilities throughout the drainage appeared to adequately supply water to sheep in all units of each allotment. In dry years, high use around large stock ponds seemed to be a function of water availability because smaller ponds dried up. Routine maintenance of existing ponds and adherence to the authorized sheep rotation pattern should optimize wise use of stock water in the drainage. On the other hand, additional stock watering facilities in upland areas may assist in keeping sheep out of fragile riparian areas in the drainage. However, sheep impact was often most noticeable in areas adjacent to water developments, and additional watering locations would undoubtedly receive high sheep impact.

Natural Mineral Licks

Fencing of the natural muck lick in Racetrack Hollow appeared to create a larger disturbed area around the perched spring, which is a source of minerals for elk. Elk seem so accustomed to these licks that they will return even if there were relatively fewer elk in the area. Noticeable springs issuing forth from steep canyon walls along Willow Creek Canyon and its tributaries were never observed to be used by elk or deer. It appears that forcing elk and deer away from currently used mineral springs by fencing will cause them to search for other mineral licks in the area. Degradation around these new mineral sources will then develop. In light of these arguments, it appears imperative that no more fencing of natural licks should occur. The Racetrack Hollow exclosure fencing should probably not be removed but should be regularly maintained. Previously described vegetation plots inside and outside its confines should be studied according to schedule to assess trends in this riparian zone.

Elk Hunting

Sport hunting of elk in the area is popular and appears to be the most feasible method to harvest surplus elk. Concern has been expressed whether anterless elk hunting should occur in the study area or whether it should be done on winter ranges. According to the Utah Division of Wildlife Resources (1994), anterless elk hunts on winter ranges result in higher hunter success; however, the anterless elk hunt held in Willow Creek in 1993 resulted in higher mortality on collared cow elk than in 1994 when anterless elk were subjected only to hunts on winter ranges. This suggests that more effective hunting of Willow Creek elk occurs on their summer range. Double hunting occurred on Willow Creek cow elk in 1993 as they traveled from summer to winter ranges (table 3); therefore, agreements with the Utah Division of Wildlife Resources Northeastern and Southeastern Regions and the Ashley National Forest may need to be made to ensure that fair and adequate harvesting of these elk occurs. Aerial locations of elk revealed that the majority of elk are already migrating to wintering areas by the end of September. This migration should be taken into account in relation to setting regular seasons and hunt boundaries for early October to ensure adequate harvesting.

Killing of only yearling bull elk to ensure mature bull numbers increase in the Diamond Fork/Strawberry elk herd (unit 21) appears successful, but poaching of mature bulls is a problem. Evidence of this was a wounded four-point bull in unit 1 of the Cabin Springs allotment on 6 October 1993, and the severed head of a five-point bull along Willow Creek in unit 1 of the Road Hollow allotment in summer 1994. Antlers were polished and hide was still intact on this severed elk head indicating that it was probably killed the previous fall (1993) or in fall 1992. Presence of older bulls in the herd will establish a more natural social structure and result in calf elk being conceived and born earlier. It is imperative that the Utah Division of Wildlife Resources continues rigorous law enforcement to control illegal killing of these mature bulls.

References

Aagard, S. 1994. [Personal communication]. Sheep Rancher. Fountain Green, Ut.

Adams, A. W. 1982. Migration. Pages 301-321 in J. W. Thomas and D. E. Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa.

Alexander, L. E., D. W. Uresk, and R. M. Hansen. 1983. Summer food habits of domestic sheep in southeastern Montana. J. Range Manage. 36:307-308.

Allen, J. A. 1874. Notes on the mammals of portions of Kansas, Colorado, Wyoming and Utah, Part IV. On the mammals of Great Salt Lake Valley, Utah. Bull. Essex Inst. 6:61-66.

Altmann, J. 1974. Observational study of behavior: sampling methods. Behaviour 49:227-265.

Anderson, E. W. 1986. A guide for estimating cover. Rangelands 8:236-238.

Anderson, J. R., W. Olkowski, and J. B. Hoy. 1974. The response of tabanid species to CO2-baited insect fly traps in northern California. Pan-Pac. Entomol. 50:255-268.

Association of Official Analytical Chemists. 1995. Official methods of analysis of AOAC international. Sixteenth ed. Association of Official Analytical Chemists. Volume 1: Agricultural chemicals; contaminants; drugs. Washington, D.C.

Applegate, K. 1994. [Personal communication]. Range Crew Leader. Utah Division of Wildlife Resources, Provo, Ut.

Baker, F. S. 1925. Aspen regeneration in the central Rocky Mountain region. U.S. Dep. Agric. Bull. 1291. Washington, D.C. 47 pp.

Barnes, C. T. 1922. Mammals of Utah. Univ. Utah Bull. 12:1-176.

Basile, J. V., and T. N. Lonner. 1979. Vehicle restrictions influence elk and hunter distribution in Montana. J. For. 77:155-159.

Bear, G. D. 1989. Seasonal distribution and population characteristics of elk in Estes Valley, Colorado. Special Report Number 65 (R-S-65-89). Colorado Division of Wildlife, Denver. 14 pp.

Beck, J. L. 1996. Elk and domestic sheep interactions in an aspen-dominated ecosystem: use of, and impacts on vegetation, habitats, and minerals, as well as implications for ecosystem management. M.S. Thesis, Brigham Young Univ., Provo, Ut. 396 pp.

Beck, J. L., J. T. Flinders, D. R. Nelson, and C. L. Clyde. 1996. Dietary overlap and preference of elk and domestic sheep in aspen-dominated habitats in north-central Utah. Pages 81-85 in K. Evans, compiler. Sharing common ground on Western rangelands: Proc. of a livestock/big game symposium. Gen. Tech. Rep. INT-GTR-343. Ogden, Ut, U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Belovsky, G. E., and P. A. Jordan. 1981. Sodium dynamics and adaptations of a moose population. J. Mammal. 62:613-621.

Bowman, D. D. 1995. Georgis' parasitology for veterinarians. Sixth ed. W. B. Saunders Co., Philadelphia, Pa. 430 pp.

Bowns, J. E., and C. F. Bagley. 1986. Vegetation responses to long-term sheep grazing on mountain ranges. J. Range Manage. 39:431-434.

Brady, N. C. 1990. The nature and property of soils. Tenth ed. Macmillan, New York, N.Y. 621 pp.

Brazda, A. R. 1953. Elk migration patterns and some of the factors affecting movements in the Gallatin River drainage, Montana. J. Wildl. Manage. 17:9-23.

Brotherson, J. D., L. A. Szyska, and W. E. Evenson. 1980. Poisonous plants of Utah. Great Basin Nat. 40:229-253.

Brown, J. K., and N. K. DeByle. 1989. Effects of prescribed fire on biomass and plant succession in western aspen. U.S. For. Serv. Res. Pap. INT-412. 16 pp.

Brown, J. K., and D. G. Simmerman. 1986. Appraising fuels and flammability in western aspen: a prescribed fire guide. U.S. For. Serv. Gen. Tech. Rep. INT-205. 48 pp.

Bryant, L. D., and C. Maser. 1982. Classification and distribution. Pages 1-59 in J. W. Thomas and D. E. Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa.

Butterfield, E. 1995. [Personal communication]. Sheep rancher. Herriman, Ut.

Calef, G. W., and G. M. Lortie. 1975. A mineral lick of the barren-ground caribou. J. Mammal. 56:240-242.

Carbyn, L. N. 1975. Factors influencing activity patterns of ungulates at mineral licks. Can. J. Zool. 53:378-384.

Cheeke, P. R., and L. R. Shull. 1985. Natural toxicants in feeds and poisonous plants. AVI Publ. Co. Inc., Westport, Conn. 492 pp.

Church, D. C., and W. G. Pond. 1988. Basic animal nutrition and feeding. Third ed. John Wiley and Sons, New York, N.Y. 472 pp.

Clegg, K. 1994. Density and feeding habits of elk and deer in relation to livestock disturbance. M.S. Thesis, Utah State Univ., Logan. 43 pp.

Clyde, C. 1993, 1994, 1995. [Personal communication]. Wildlife Biologist. Central Region, Utah Division of Wildlife Resources, Springville, Ut.

Cole, G. F. 1959. Key browse survey method. Proc. West. Assoc. State Game and Fish Comm. 39:181-186.

Collins, W. B., and P. J. Urness. 1982. Mule deer and elk responses to horsefly attacks. Northwest Sci. 56:299-302.

Cook, C. J., C. W. Cook, and L. E. Harris. 1948. Utilization of northern Utah summer range plants by sheep. J. For. 46:416-425.

Coop, K. J. 1971. Habitat use, distribution, movement, and associated behavior of elk, Little Belt, Montana. Compl. Rep. Proj. No. W-120-R-1 & 2, pp. 61. Montana Fish and Game Dep., Helena.

Cordova, F. J., J. D. Wallace, and R. D. Pieper. 1978. Forage intake by grazing livestock: a review. J. Range Manage. 31:430-438.

Cowan, I. McT., and V. C. Brink. 1949. Natural game licks in the Rocky Mountain National Parks of Canada. J. Mammal. 30: 379-387.

Craighead, J. J., F. C. Craighead, Jr., R. L. Ruff, and B. W. O'Gara. 1973. Home ranges and activity patterns of nonmigratory elk of the Madison Drainage herd as determined by biotelemetry. Wildl. Monogr. No. 33. 50 pp.

Crosland, R. I. 1993. Mobility strategies of Archaic and Fremont Peoples: faunal evidence from Aspen Shelter (42Sv 1365), Utah. M.S. Thesis, Brigham Young Univ., Provo, Ut. 141 pp. Dalke, P. D., R. D. Beeman, F. J. Kindel, R. J. Robel, and T. R. Williams. 1965. Use of salt by elk in Idaho. J. Wildl. Manage. 29:319-332.

Darling, F. F. 1937. A herd of red deer: a study in the animal behaviour. London, Oxford Univ. Press. 215 pp.

daSilveira, A. J., F. F. F. Teles, and J. Warren. 1978. A rapid technique for total nonstructural carbohydrate determination of plant tissue. J. Agric. Food Chem. 26:771-772.

Dawson, M. R. 1967. Fossil history of the families of recent mammals. Pages 12-53 in S. Anderson and J. N. Jones, Jr., eds. Recent mammals of the world. Ronald Press Co., New York, N.Y.

DeByle, N. V. 1976. The aspen forest after harvest. Pages 35-40 in Proc. Symp., utilization and marketing as tools in aspen management in the Rocky Mountains. U.S. For. Serv. Gen. Tech. Rep. RM-29, 120 pp. Rocky Mt. For. and Range Exp. Sta., Fort Collins, Colo.

DeByle, N. V. 1985. Animal impacts. Pages 115-123 in N. V. DeByle and R. P. Winokur, eds. Aspen: ecology and management in the western United States. U.S. For. Serv. Gen. Tech. Rep. RM-119.

DePietro, M. 1993. [Personal communication]. Supervisory Rangeland Management Specialist. Spanish Fork Ranger District, Uinta National Forest, Spanish Fork, Ut.

Downes, C. M., J. B. Theberge, and S. M. Smith. 1986. The influence of insects on the distribution, microhabitat choice, and behavior of the Burwash caribou herd. Can. J. Zool. 64:622-629.

Duke, J. A. 1977. Phytotoxin tables. Clin. Rev. Toxic. 5:189-238.

Durrant, S. D. 1952. Mammals of Utah: taxonomy and distribution. Univ. Kansas Nat. Hist. Mus. Publ., Lawrence. 549 pp.

Edge, W. D., and C. L. Marcum. 1985. Movements of elk in relation to logging disturbances. J. Wildl. Manage. 49:926-930.

Edge, W. D., C. L. Marcum, and S. L. Olsen-Edge. 1988. Summer forage and feeding site selection by elk. J. Wildl. Manage. 52: 573-577.

Edwards, T. C., Jr., C. G. Homer, S. D. Bassett, A. Falconer, R. D. Ramsey, and D. W. Wight. 1995. Utah gap analysis: an environmental analysis system. Final Proj. Rep. 95-1. Utah Coop. Fish and Wildl. Res. Unit, Utah State Univ., Logan. 38 pp.

Ellison, L. 1954. Subalpine vegetation of the Wasatch Plateau, Utah. Ecol. Monogr. 24:89-184.

Espmark, Y., and R. Langvatn 1979. Lying down as a means of reducing fly harassment in red deer (*Cervus elaphus*). Behav. Ecol. Sociobiol. 5:51-54.

Flinders, J. T. 1988. Essential habitat for wildlife. Pages 43-55 in B. A. Buchanan, ed. Rangelands. Univ. New Mexico Press, Albuquerque.

Flinders, J. T., and R. M. Hansen. 1972. Diets and habitats of jackrabbits in northeastern Colorado. Range Sci. Dep. Sci. Ser. No. 12., Colorado State Univ., Fort Collins. 29 pp.

Fraser, D., E. Reardon, F. Dieken, and B. Loescher. 1980. Sampling problems and interpretation of chemical analysis of mineral springs used by wildlife. J. Wildl. Manage. 44:623-631.

Fraser, D., and E. R. Thomas. 1982. Moose-vehicle accidents in Ontario: relation to highway salt. Wildl. Soc. Bull. 10:261-265.

French, C. E., L. C. McEwen, N. D. Magruder, R. H. Ingram, and R. W. Swift. 1955. Nutritional requirements of white-tailed deer for growth and antler development. Bull. 600. Pennsylvania Argic. Exp. Sta., State College, Pa. 50 pp.

Fryxell, J. M. 1991. Forage quality and aggregation by large herbivores. Am. Nat. 138:478-498.

Geist, V. 1971. Mountain sheep—a study in behavior and evolution. Univ. Chicago Press, Chicago, Ill. 383 pp.

Geist, V. 1982. Adaptive behavioral strategies. Pages 219-277 in J. W. Thomas and D. E. Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa.

Geist, V., and M. H. Francis. 1990. In the beginning. Pages 12-31 in Mule deer country. NorthWord Press, Inc., Minocqua, Wis.

Geist, V., and M. H. Francis. 1991. From beyond Siberia. Pages 28-49 in Elk Country. NorthWord Press, Inc., Minocqua, Wis.

Gibson, C. W. D., and V. K. Brown. 1992. Grazing and vegetation change: deflected or modified succession? J. Appl. Ecol. 29: 120-131.

Giles, R. H., Jr. 1978. Wildlife management. G. W. Salisbury, ed. W. H. Freeman and Co. San Francisco, Calif. 416 pp.

Graves, H. S., and E. W. Nelson. 1919. A program for conserving the elk on national forests about the Yellowstone National Park. Dep. Circ. 51. Washington, D.C.: U.S. Dep. Agric. 34 pp.

Green, A. W., and T. S. Setzer. 1974. The Rocky Mountain timber situation, 1970. U.S. For. Serv. Resour. Bull. INT-10. 78 pp.

Greenway, S. H. 1990. Aspen regeneration: a range management problem. Rangelands 12:21-23.

Greer, K. R., and R. E. Howe. 1964. Winter weights of northern Yellowstone elk, 1961-62. Trans. N. Am. Wildl. Conf. 29:237-248.

Grover, K. E., and M. J. Thompson. 1986. Factors influencing spring feeding site selection by elk in the Elkhorn Mountains, Montana. J. Wildl. Manage. 50:466-470.

Grumbine, R. E. 1994. What is ecosystem management? Conserv. Biol. 8:27-38.

Hamilton, C. L., and H. G. Jepson. 1940. Stock-water developments: wells, springs, and ponds. USDA Farmer's Bull. 1859. 70 pp.

Hamilton, W. D. 1971. Geometry for the selfish herd. J. Theoretical Biol. 31:295-311.

Hanley, T. A. 1980. Nutritional constraints on food and habitat selection by sympatric ungulates. Ph.D. Dissertation, Univ. Washington, Seattle. 176 pp.

Harper, K. T. 1986. Historical environments. Pages 51-63 in L. D. 'Azevedo, ed. Handbook of North American Indians, Vol. 11. Smithsonian Inst., U.S. Gov. Printing Off., Washington, D.C.

Hayne, D. W. 1949. An examination of the strip census method for estimating animal populations. J. Wildl. Manage. 13:145-157.

Herbert, D., and I. M. Cowan. 1971. Natural salt licks as a part of the ecology of the mountain goat. Can J. Zool. 49:605-610.

Hibler, C. P., and J. L. Adcock. 1971. Elaeophorosis. Pages 263-268 in J. W. Davis and R. C. Anderson, eds. Parasitic diseases of wild mammals. Iowa State Univ. Press, Ames.

Hofmann, R. R. 1988. Anatomy of the gastro-intestinal tract. Pages 14-43 in D. C. Church, ed. The ruminant animal: digestive physiology and nutrition. Prentice Hall, Englewood Cliffs, N.J.

Holl, S. A., and V. C. Bleich. 1987. Mineral lick use by mountain sheep in the San Gabriel Mountains, California. J. Wildl. Manage. 51:383-385.

Hopkins, D. M. 1967. Introduction. Pages 1-6 in D. M. Hopkins, ed. The Bering Land Bridge. Stanford Univ. Press, Stanford, Calif.

Hornocker, M. G. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildl. Monogr. No. 21. 39 pp.

Houston, W. R. 1954. A condition guide for aspen ranges of Utah, Nevada, southern Idaho, and western Wyoming. USDA, Intermountain For. and Range Exp. Stat., Stat. Pap. 32. Ogden, Ut. 17 pp.

Hulet, B. V. 1983. Selected responses of sage grouse to prescribed fire, predation and grazing by domestic sheep in southeastern Idaho. M.S. Thesis, Brigham Young Univ., Provo, Ut. 64 pp.

Hyvarinen, H., T. Helle, M. Nieminen, P. Vayrynen, and R. Vayrynen. 1977. The influence of nutrition and seasonal conditions on mineral status in reindeer. Can. J. Zool. 55:648-655.

Irwin, L. L., and J. M. Peek. 1983. Elk habitat use relative to forest succession in Idaho. J. Wildl. Manage. 47:664-672.

Ivlev, V. S. 1961. Experimental ecology of the feeding fishes. Yale Univ. Press, New Haven, Conn. 302 pp.

Janis, C. 1976. The evolutionary strategy of the equidae and the origins of rumen and cecal digestion. Evolution 30:757-774.

Johnsgard, P. A. 1973. Grouse and quails of North America. Univ. Nebraska Press, Lincoln. 533 pp.

Johnson, D. E. 1951. The biology of the elk calf, *Cervus canadensis nelsoni*. J. Wildl. Manage. 15:396-410.

Johnson, H. B. 1964. Changes in the vegetation of two restricted areas of the Wasatch Plateau as related to reduced grazing and complete protection. M.S. Thesis, Brigham Young Univ., Provo, Ut. 123 pp.

Jones, J. R., and N. V. DeByle. 1985. Fire. Pages 77-81 in N. V. DeByle, and R. P. Winokur, eds. Aspen: ecology and management in the western United States. U.S. For. Serv. Gen. Tech. Rep. RM-119.

Jones, O. M. 1922. Ninth biennial report of the fish and game warden of the State of Idaho, 1921-22. 158 pp.

Jones, R. L., and H. C. Hanson. 1985. Mineral licks, geophagy, and biogeochemistry of North American ungulates. Iowa State Univ. Pres., Ames. 301 pp.

Jones, Y. F., and E. K. Jones. 1972. Lehi Willard Jones 1854-1947. Woodruff Printing Co., Salt Lake City, Ut. 258 pp.

Kincaid, R. 1988. Macro elements for ruminants. Pages 326-341 in D. C. Church, ed. The ruminant animal: digestive physiology and nutrition. Prentice Hall, Englewood Cliffs, N.J.

Kindel, F. J. 1958. Salt in the management of elk and other wildlife in the vicinity of Clearwater Ridge area of Idaho. Project Rep. W-85-R-8. Univ. Idaho, Moscow. 69 pp.

King, R. T. 1937. Ruffed grouse management. J. For. 35:523-532.

Kingsbury, J. M. 1964. Poisonous plants of the United States and Canada. Prentice-Hall Inc., Englewood Cliffs, N.J. 626 pp.

Kistner, T. P., K. R. Greer, D. E. Worley, and O. A. Brunetti. 1982. Diseases and parasites. Pages 181-217 in J. W. Thomas and D. E. Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa.

Knight, R. R., and M. R. Mudge. 1967. Characteristics of some natural licks in the Sun River Area, Montana. J. Wildl. Manage. 31:293-299.

Knowles, C. J., and R. B. Campbell. 1982. Distribution of elk and cattle in a rest-rotation grazing system. Pages 47-60 in J. M. Peek and P. D. Dalke, eds. Proc. wildl.-livestock relationships symp. Univ. Idaho For., Wildl. and Range Exp. Stn., Moscow, Idaho.

Krebs, C. J. 1989. Ecological methodology. Harper and Row, New York, N.Y. 654 pp.

Kurtén, B., and E. Anderson. 1980. Pleistocene mammals of North America. Columbia Univ., Press, New York, N.Y. 442 pp.

Lavertu, D., Y. Mauffette, and Y. Bergeron. 1994. Effects of stand age and litter removal on the regeneration of *Populus tremuloides*. J. Vegetation Sci. 5:561-568.

Lincoln, F. C. 1930. Calculating waterfowl abundance on the basis of banding returns. U.S. Dep. Agric. Cir. 118:1-4.

Lorenz, R. J., and S. A. Dewey. 1988. Pages 309-336 in L. F. James, M. H. Ralphs, and D.B. Nielsen, eds. The ecology and economic impact of poisonous plants on livestock production. Westview Press, Boulder, Colo.

Lorimer, C. G. 1990. Silviculture. Pages 300-325 in R. A. Young and R. L. Giese, eds. Introduction to Forest Science. Second ed. John Wiley and Sons, New York, N.Y.

Lyon, L. J., and A. L. Ward. 1982. Elk and land management. Pages 443-477 in J. W. Thomas and D. E. Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa.

MacCracken, J. G., and R. M. Hansen. 1981. Diets of domestic sheep and other large herbivores in southcentral Colorado. J. Range Manage. 34:242-243.

Mackie, R. J. 1970. Range ecology and relations of mule deer, elk and cattle in the Missouri River Breaks, Montana. Wildl. Monogr. No. 20. 79 pp.

Mantz, G. K. 1993. Spring elk effects on the availability of summer cattle forage in the Uinta Mountains of Utah. M.S. Thesis, Utah State Univ., Logan. 72 pp.

Marcum, C. L. 1976. Habitat selection and use during summer and fall months by a western Montana elk herd. Pages 91-96 in S. R. Hieb, ed. Proc. Elk-Logging-Roads Symp., Univ. Idaho, Moscow.

Marcum, C. L., and M. D. Scott. 1985. Influences of weather on elk use of spring-summer habitat. J. Wildl. Manage. 49:73-76.

Matthews, V. B. 1965. An ecological life history of tall bluebell in Utah. M.S. Thesis, Brigham Young Univ., Provo, Ut. 119 pp.

Mecke, M. 1979. The poisonous range plants of Wyoming. M.S. Thesis, Univ. Wyoming, Laramie. 136 pp.

Meinecke, E. P. 1929. Quaking aspen: a study in applied forest pathology. U.S. Dep. Agric., Tech. Bull. 155. Washington, D.C. 34 pp.

Minitab. 1993. Minitab reference manual: release 9 for windows. Sowers Printing Co., Lebanon, Pa. 472 pp.

Mohler, L. L., and D.E. Toweill. 1982. Regulated elk populations and hunter harvests. Pages 561-597 in J. W. Thomas and D. E. Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa.

Mooring, M. S., and B. L. Hart. 1992. Animal grouping for protection from parasites: selfish herd and encounter-dilution effects. Behaviour 123:173-193.

Morgantini, L. E., and R. J. Hudson. 1979. Human disturbance and habitat selection in elk. Pages 132-139 in M. S. Boyce and L. D. Hayden-Wing, eds. North American elk: ecology, behavior, and management. Univ. Wyoming, Laramie.

Mueggler, W. F. 1985. Forage. Pages 129-134 in N. V. DeByle, and R. P. Winokur, eds. Aspen: ecology and management in the western United States. U.S. For. Serv. Gen. Tech. Rep. RM-119.

Mueggler, W. F. 1989. Age distribution and reproduction of Intermountain aspen stands. West. J. Appl. For. 4:41-45.

Muller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology, Wiley, New York, N.Y.

Murie, O. J. 1951. The elk of North America. Stackpole Books, Harrisburg, Pa. 376 pp.

National Geographic Society. 1991. Field guide to the birds of North America. Second ed. Arcata Graphics-Kingsport, Kingsport, Tenn. 464 pp.

National Research Council. 1985. Nutrient requirements of sheep. Sixth rev., ed. Natl. Acad. Sci., Washington, D.C. 99 pp.

Nelson, D. 1995. [Personal communication]. Ecologist. Uinta National Forest, Provo, Ut.

Nelson, J. R. 1982. Relationships of elk and other large herbivores. Pages 415-441 in J. W. Thomas and D. E. Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa.

Nelson, J. R., and T. A. Leege. 1982. Nutritional requirements and food habits. Pages 323-367 in J. W. Thomas and D. E. Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa.

Nichols, L., Jr. 1957a. Forage utilization by elk and domestic sheep in the White River National Forest. M.S. Thesis, Colorado State Univ., Fort Collins. 92 pp.

Nichols, L., Jr. 1957b. Study of forage utilization by elk and domestic sheep on the South Fork of the White River. Compl. Rep., Proj. W-38-R-10, pp. 11-22. Colorado Fish and Game Dep., Denver.

Oh, H. K., T. Sakai, M. B. Jones, and W. M. Longhurst. 1967. Douglas fir needles effect upon sheep and deer rumen microbial activity. Appl. Micro. 4:777-784.

Olmsted, C. E. 1979. The ecology of aspen with reference to utilization by large herbivores in Rocky Mountain National Park. Pages 89-97 in M. S. Boyce and L. D. Hayden-Wing, eds. North American elk: ecology, behavior, and management, Univ. Wyoming, Laramie.

Olsen, F. W., and R. M. Hansen. 1977. Food relationships of wild free-roaming horses to livestock and big game, Red Desert, Wyoming. J. Range Manage. 30:17-20.

Oosting, H. J. 1956. The study of plant communities. W. H. Freeman and Co., San Francisco, Calif. 440 pp.

Ostler, W. K., K. T. Harper, K. B. McKnight, and D. C. Anderson. 1982. The effects of increasing snowpack on a subalpine meadow in the Uinta Mountains, Utah U.S.A. Arctic and Alpine Res. 14:203-214.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildl. Mono. No. 62. 135 pp.

Ott, R. L. 1993. An introduction to statistical methods and data analysis. Fourth ed. Duxbury Press, Belmont, Calif. 1051 pp.

Pickford, G. D., and E. H. Reid. 1943. Competition of elk and domestic livestock for summer range forage. J. Range Manage. 7:328-332.

Pletscher, D. H. 1987. Nutrient budgets for white-tailed deer in New Hampshire with special reference to sodium. J. Mammal. 68: 330-336.

Prothero, W. L., J. J. Spillett, and D. F. Balph. 1979. Rutting behavior of yearling and mature bull elk: some implications for open bull elk hunting. Pages 160-165 in M. S. Boyce and L. D. Hayden-Wing, eds. North American elk: ecology, behavior, and management. Univ. Wyoming, Laramie.

Quimby, D. C., and D. E. Johnson. 1951. Weights and measurements of Rocky Mountain elk. J. Wildl. Manage. 15:57-62.

Ralley, W. E., T. D. Galoway, and G. H. Crow. 1993. Individual and group behaviour of pastured cattle in response to attack by biting flies. Can. J. Zool. 71:725-734.

Ratti, J. T., and L.W. Ratti. 1988. Manuscript guidelines for The Journal of Wildlife Management. J. Wildl. Manage. 52 (1, Suppl.). 34 pp.

Rhodes, B. D., and S. H. Sharrow. 1990. Effect of grazing by sheep on the quantity and quality of forage available to big game in Oregon's Coast Range. J. Range Manage. 43:235-237.

Robbins, C. T. 1993. Wildlife feeding and nutrition. Second ed. Academic Press, Inc. San Diego, Calif. 352 pp.

Robinson, W. L., and E. G. Bolen. 1989. Wildlife ecology and management. Second ed. Macmillan, New York, N.Y. 574 pp.

Rosenfeld, I., and O. A. Beath. 1964. Selenium: geobotany, biochemistry, toxicity and nutrition. Academic Press, New York, N.Y. 411 pp.

Ruyle, G. B., and D. D. Dwyer. 1985. Feeding stations of sheep as an indicator of diminished forage quality. J. Anim. Sci. 61:349-353.

Salisbury, F. B., and C. W. Ross. 1992. Plant physiology. Fourth ed. Wadsworth, Publ. Co., Belmont, Calif. 682 pp.

Schier, G. A. 1981. Aspen regeneration. Pages 15-21 in N. V. DeByle, ed. Symp. Proc., situation management of two Intermountain species: aspen and coyotes. Utah State Univ., Logan. Intermountain For. and Range Exp. Sta., Logan, Ut.

Schmutz, E. M., B. N. Freeman, and E. R. Reed. 1968. Livestock-poisoning plants of Arizona. Univ. Arizona Press, Tucson. 176 pp.

Scott, J. M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'erchia, T. C. Edwards, Jr., J. Ulliman, and R. G. Wright. 1993. Gap analysis: a geographic approach to protection of biological diversity. Wildl. Monogr. No. 123. 41 pp.

Seton, E. T. 1909. Life-histories of northern mammals. Vol. 1. Grass-eaters. Charles Scribner's Sons. New York, N.Y. 673 pp.

Seton, E. T. 1927. Lives of game animals. Vol. 3, part 1. Doubleday, Page and Co., Garden City, N.Y. 412 pp.

Shannon, N. H., R. J. Hudson, V. C. Brink, and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. J. Wildl. Manage. 39:387-401.

Shields, P. W. 1981. Opportunities for wildlife habitat management in aspen. Pages 69-76 in N. V. DeByle, ed. Symp. Proc., situation management of two Intermountain species: aspen and coyotes. Utah State Univ., Logan, Intermountain For. and Range Exp. Sta., Logan, Ut.

Shiozawa, D. K., and R. P. Evans. 1993. An appraisal of Cutthroat trout purity from Willow Creek and the Duchesne River in the Uinta National Forest. Final Rep. to Heber District, Uinta National Forest under Order Number 43-8462-2-4886. 6 pp.

Skovlin, J. M. 1982. Habitat requirements and evaluations. Pages 369-413 in J. W. Thomas and D. E. Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa.

Smith, K. J. 1991. Trigonometry for college students. Fifth ed. Brooks/Cole Publ. Co. Pacific Grove, Calif. 410 pp.

Smith, S. 1993, 1994, 1995. [Personal communication]. Supervisory Rangeland Management Specialist. Heber Ranger District, Uinta National Forest, Heber City, Ut.

Smith, T. S. 1991. The bighorn sheep of Bear Mountain: ecological investigations and management recommendations. Ph.D. Dissertation, Brigham Young, Univ., Provo, Ut. 395 pp.

Society of American Foresters. 1955. Forestry Handbook. R. D. Forbes, ed. Ronald Press Co., New York, N.Y. 1047 pp.

Squibb, R. C. 1985. Mating success of yearling and older bull elk. J. Wildl. Manage. 49:744-750.

Stephens, H. A. 1980. Poisonous plants of the Central United States. University Press of Kansas, Lawrence. 165 pp.

Stevens, D. R. 1966. Range relationships of elk and livestock, Crow Creek drainage, Montana. J. Wildl. Manage. 30:349-363.

Stockstad, D. S., M. S. Morris, and E. C. Lory. 1953. Chemical characteristics of natural licks used by big game animals in western Montana. Trans. N. Amer. Wildl. Conf. 18:247-258.

Strickberger, M. W. 1990. Evolution. Jones and Bartlett, Publ. Co., Boston, Mass. 579 pp.

Tashiro, H., and H. H. Schwardt. 1953. Biological studies of horse flies in New York. J. Econ. Entomol. 46:813-822.

Thomas, J. W., editor. 1979. Wildlife habitats in managed forests—the Blue Mountains of Oregon and Washington. Handbook No. 533. U.S. Dep. Agric., Washington, D.C. 512 pp.

Thomas, J. W., R. J. Miller, H. Black, J. E. Rodiek, and C. Maser. 1976. Guidelines for maintaining and enhancing wildlife habitat in forest management in the Blue Mountains of Oregon and Washington. Trans. N. America. Wildl. and Nat. Res. Conf. 41: 452-476.

Thomas, R. E. 1926. Eleventh biennial report of the fish and game warden of the State of Idaho, 1925-26. 123 pp.

Tsvelev, N. N. 1984. Grasses of the Soviet Union. Parts 1 and 2. Russian Translation Series 8. A. A. Balkema, Rotterdam. 1196 pp.

U.S. Forest Service. 1972. V. K. Isbell, ed. Historical development of the Spanish Fork Ranger District. Uinta National Forest, Provo, Utah. 165 pp.

U.S. Forest Service. 1993. Final environmental impact Statement for rangeland ecosystem management on the Uinta National Forest. Uinta National Forest, Provo, Ut. 195 pp.

U.S. Natural Resources Conservation Service. 1994. Utah cooperative snow survey data of Federal-State-private cooperative snow surveys: water year 1994. Natural Resources Conservation Service, Salt Lake City, Ut. 31 pp.

U.S. Soil Conservation Service. 1993. Utah cooperative snow survey data of Federal-State-private cooperative snow surveys: water year 1993. Soil Conservation Service, Salt Lake City, Ut. 32 pp.

Utah Division of Wildlife Resources. 1992. Utah big game annual report. Utah Dep. Nat. Resour. Publ. 92-13. Utah Div. Wildl. Resour., Salt Lake City.

Utah Division of Wildlife Resources. 1994. Utah big game annual report. Annual Perf. Rep. for Fed. Aid Proj. W-65-RD-41, Job A2. Utah Dep. Nat. Res. Publ. 94-6. Utah Div. Wildl. Resour., Salt Lake City.

Vallentine, J. F. 1989. Range development and improvements. Third ed. Academic Press, Inc, San Diego, Calif. 524 pp.

Vallentine, J. F. 1990. Grazing management. Academic Press, Inc., San Diego, Calif. 533 pp.

Vallentine, J. F., R. P. Shumway, and S. C. James. 1984. "Cattle ranch planning manual." Brigham Young Univ. Publ., Provo, Ut. 315 pp.

Ward, A. L. 1973. Elk behavior in relation to multiple uses on the Medicine Bow National Forest. Proc. West. Assoc. State Game and Fish Comm. 53: 125-141.

Watts, T. J., and S. D. Schemnitz. 1985. Mineral lick use and movement in a remnant desert bighorn sheep population. J. Wildl. Manage. 49:994-996.

Weeks, H. P., Jr. 1978. Characteristics of mineral licks and behavior of visiting white-tailed deer in southern Indiana. Am. Midl. Nat. 100:384-385.

Weeks, H. P., Jr., and C. M. Kirkpatrick. 1976. Adaptations of white-tailed deer to naturally occurring sodium deficiencies. J. Wildl. Manage. 40:610-625.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins, eds. 1993. A Utah flora. Second ed., rev. Print Services, Brigham Young Univ., Provo, Ut. 986 pp.

Whitson. T. D., M. A. Ferrell, S. D. Miller, S. A. Dewey, J. O. Evans, and R. J. Shaw. 1987. Weeds and poisonous plants of Utah and Wyoming. B-855-UW, Res. Rep. 116-USU. Univ. Wyoming, Laramie. 280 pp.

Wickstrom, M. L., C. T. Robbins, T. A. Hanley, D. E. Spalinger, and S. M. Parish. 1984. Food intake and foraging energetics of elk and mule deer. J. Wildl. Manage. 48:1285-1301.

Willms, W., and A. McClean. 1978. Spring forage selection by tame mule deer on big sagebrush range, British Columbia. J. Range Manage. 31:192-199.

Wilson, H. 1995. [Personal communication]. Sheep rancher. Payson, Ut.

Wilson, R. 1994. [Personal communication]. Hydrologist. Natural Resources Conservation Service. Salt Lake City, Ut.

Wilson, V. 1993. [Personal communication]. Sheep rancher. Payson, Ut.

Winn, D. S. 1976. Terrestrial vertebrate fauna and selected coniferous habitat types on the north slope of the Uinta Mountains. Wasatch Nat. For. Spec. Rep. USDA For. Serv. Salt Lake City, Ut. 145 pp.

Zeveloff, S. I., and F. R. Collett. 1988. Mammals of the Intermountain West. Univ. Utah Press, Salt Lake City. 365 pp.

Appendix A: Forage Use; Percent of Plant Individuals Utilized; Kulcynski's Forage Use and Dietary Overlap Similarity Indices; and Ivlev's Electivity Indices of Forage Preference

Table A1—Relative proportions of dry biomass (of forbs, grasses, sedges, rushes, and browse) in the diets of elk in spring, 1993 and 1994; and the percent use of forb, grass, sedge, rush, and browse standing biomass in spring, 1993 and 1994. Browse (1994 only) percent biomass used based on percent use of available (0-1.83 m) browse biomass.

	Spring 1993		Spring 1994	
Species	Diet[a]	Use biomass[a]	Diet[a]	Use biomass[a]
	- - - - - - - - - -	- - - - - - - - - - *Percent*	- - - - - - - - - -	- - - - - - - - - -
Forbs				
Achillea millefolium	0.00	0.00	0.31	0.62
Agastache urticifolia	0.29	0.60	0.00	0.00
Agoseris glauca			0.00	0.00
Androsace septentrionalis			0.00	0.00
Arabis drummondii			0.00	0.04
Artemisia cana[b]			0.00	0.00
Artemisia dracunculus			0.00	0.00
Artemisia michauxiana	0.00	0.00	0.19	1.70
Aster chilensis			0.00	0.00
Aster foliaceous	2.89	2.40		
Calachortus nuttallii			0.11	3.00
Chenopodium capitatum			0.05	3.00
Chenopodium fremontii			0.00	0.00
Chrysothamnus viscidiflorus[b]			0.00	0.00
Clematis hirsutissima			1.61[c]	7.85
Delphinium nuttallianum	0.62	4.00	0.11	8.88
Delphinium occidentale			0.00	0.00
Descurainia californica	0.00	0.00	0.45	2.14
Erigeron ursinus			0.00	0.00
Fragaria vesca	0.00	0.00	0.30	0.27
Fritillaria atropurpurea			0.00	0.00
Geranium viscosissimum	0.56	1.15	1.11	0.81
Hackelia floribunda			0.00	0.00
Lathyrus lanzwertii			0.81	3.67
Lepedium densiflorum			0.00	0.00
Lesquerella alpina			0.00	0.00
Linum perenne			0.00	0.00
Lomatium graveolens			0.00	0.00
Lupinus lepidus			0.00	0.00
Lupinus sericeus	0.00	0.00	0.15	0.40
Mertensia brevistyla			0.00	0.00
Mertensia arizonica	56.29[c]	12.66	26.52[c]	8.50
Nemophila breviflora			0.02	0.34
Orthocarpus tolmei			0.00	0.00
Penstemon cyananthus			0.70	8.00
Phacelia hastata			0.00	0.00
Phlox longifolia			0.00	0.00
Polygonum douglasii			0.00	0.00
Potentilla anserina	0.00	0.00	2.06[c]	2.27
Ranunculus inamoenus			0.46	5.38
Senecio multilobatus			0.00	0.00
Senecio serra	0.00	0.00	0.00	0.00
Smilacina stellata	0.00	0.00	0.00	0.00
Stellaria jamesiana	0.00	0.00	0.25	1.72
Taraxacum officinale			0.07	1.71

(con.)

Table A1 (Con.)

	Spring 1993		Spring 1994	
Species	**Diet**[a]	**Use biomass**[a]	**Diet**[a]	**Use biomass**[a]
	Percent			
Tragopogon dubuis			0.24	14.80
Unknown forb	0.00	0.00		
Urtica dioica			0.00	0.00
Valeriana occidentalis			0.25	7.50
Vicia americana	0.00	0.00	0.76	1.90
Viola nuttallii	0.00	0.00	0.44	1.64
Viola purpurea			0.00	0.00
Grasses				
Bromus anomalus			0.00	0.00
Bromus carinatus	12.74[c]	4.44	9.65[c]	6.35
Bromus inermis			10.15[c]	4.22
Elymus spicatus			7.78[c]	12.40
Elymus trachycaulus	1.44	3.20	22.11[c]	6.82
Melica bulbosa	1.89	4.50	0.55	3.19
Poa fendleriana			0.00	0.00
Poa pratensis	0.39	0.50	3.55[c]	1.19
Poa secunda			0.54	4.00
Stipa lettermanii	6.74[c]	3.54	1.57[c]	0.84
Stipa nelsoni	1.91	2.30	3.72[c]	2.68
Sedges and rushes				
Carex douglasii			0.00	0.00
Carex hoodii	14.26[c]	4.44	2.45[c]	1.98
Cares stenophylla			0.00	0.00
Carex vallicola			0.06	0.70
Juncus arcticus			0.59	1.30
Browse				
Artemisia cana				
Artemisia tridentata				
Chrysothamnus nauseosus			0.00	0.5
Chrysothamnus viscidiflorus				
Populus tremuloides				
Ribes cereum				
Ribes montigeneum			0.16[d]	2.00
Sambucus racemosa				
Symphoricarpos oreophilus			0.16[d]	10.20

[a] Values of zero (0.00) indicate that the species was present in spring elk feeding sites but was not used.

[b] Woody plants with a basal stem diameter ≤.32 cm were considered to be forbs due to their small size and forb-like texture.

[c] These species composed at least 90 percent of elk spring diets and were subjected to nutritional analyses. In spring 1993, four species composed 90.0 percent of elk diets. In spring 1994, 11 species composed 91.2 percent of elk diets.

[d] These species composed less than 90 percent of elk spring diets but were subjected to nutritional analyses.

Table A2—Percent of forb, grass, sedge, rush, and browse individuals utilized by elk and domestic sheep seasonally, 1993 and 1994. Browse in 1994 are collectively considered to be mature = M (≥1.3 cm diameter basal stem), and in 1993 are listed as young = Y (0.32 to 1.3 cm diameter basal stem) and mature.

Species	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
	Spring	Summer	Fall^{a}	Summer	Fall	Spring	Summer	Fall^{a}	Summer	Fall
	Mean									
Forbs										
Achillea millefolium	0.5	2.3^{b}	5.0	6.4	4.0	1.3	4.5	16.0	11.9	2.0
Agastache urticifolia	2.0	25.0	0.0	80.0	75.0	0.0	15.0		0.0	
Agoseris glauca		0.0		0.0		5.0				
Androsace septentrionalis	0.0	0.0		0.0	0.0	0.0	0.0		0.0	0.0
Antennaria microphylla									0.0	
Antennaria parvifolia					0.0				9.5	
Arabis drummondii					0.0	9.5	1.5	0.0	18.5	0.0
Artemisia cana^{c}		0.0		1.0	0.0	0.0	0.0		0.0	
Artemisia dracunculus		14.0		25.0		0.0				
Artemisia ludoviciana		0.0				0.0	14.7			
Artemisia michauxiana	0.0	7.5				0.0	2.0	86.0	36.5	92.0
Artemisia tridentata^{c}		0.0		0.0^{d}	0.0	0.0			0.0	3.0
Aster chilensis				29.0		0.0				
Aster foliaceous	1.0	1.0							59.0	
Astragalus agrestis									0.0	23.0
Astragalus convularis				0.0					16.5	
Astragalus argophyllus									0.0	
Calochortus nuttallii				0.0		24.0			0.0	
Castilleja linariifolia						14.0				
Chenopodium capitatum						0.0				
Chenopodium fremontii	0.0	0.1	0.0	2.4	51.0	0.0	0.0	4.0	0.0	28.0
Chrysothamnus nauseosus^{c}						0.0				
Chrysothamnus viscidiflorus^{c}		0.0		0.6	0.0	0.0	0.0	0.0	0.0	0.0
Clematis hirsutissima				0.0		18.3			85.0	
Collomia debilis							0.0			
Collomia linearis					67.0		0.0		0.0	
Crepis acuminata				25.0						
Descurainia californica	0.0	0.1	5.0	0.0	29.0	0.0	0.0	0.0	10.3	
Descurainia sophia						0.0				
Delphinium nuttallianum	2.0			28.0		0.0	0.0			
Delphinium occidentale		0.0		100.0		0.0				
Draba crassifolia				0.0						
Erigeron eatonii		33.5			67.0	0.0				
Erigeron elatior		16.0								
Erigeron speciosus							87.0		95.0	100.0
Erigeron ursinus		1.3		4.3	5.0	4.7		20.0	48.5	
Euphorbia brachycera							100.0			
Fragaria vesca	0.0	3.5		16.9	11.0	0.0	1.0	0.0	9.2	17.0
Fritillaria atropurpurea		0.0				0.0				
Galium bifolium	0.0				0.0				0.0^{d}	
Galium boreale				55.0		0.0	0.67		0.0	
Gentianella amarella				0.0	100.0		0.0		0.0	0.0
Geranium viscosissimum	3.0	8.3		59.8		3.3	66.5	0.0	83.5	
Geum macrophyllum									0.0	
Hackelia floribunda		6.0		66.7	75.0	8.5			45.3	100.0
Heracleum lanatum							0.0			
Hydrophyllum capitatum							0.0		67.0	
Lathyrus lanzwertii		0.0		30.0	56.0	0.4	7.0		9.0	80.0
Lepidium densiflorum	0.0			0.0	0.0	0.0	0.0		0.0	
Lesquerella alpina		0.0		0.0		0.0			0.0	
Linum perenne		0.0				0.0				
Lomatium graveolens						0.0				
Lupinus lepidus		0.0			30.0	0.0				
Lupinus sericeus	0.0	35.0		0.0		0.0	0.0		34.8	100.0
Mertensia arizonica	10.0	50.3		51.6^{d}	60.0	19.9	70.0	100.0	74.3	
Mertensia brevistyla						0.0				
Monolepis nuttalliana				17.0						
Nemophila breviflora					0.0	0.0			0.0	
Orthocarpus tolmei		25.0		3.0		0.0				

(con.)

Table A2 (Con.)

Species	1993 Elk Spring	1993 Elk Summer	1993 Elk Fall^{a}	1993 Sheep Summer	1993 Sheep Fall	1994 Elk Spring	1994 Elk Summer	1994 Elk Fall^{a}	1994 Sheep Summer	1994 Sheep Fall
	Mean									
Osmorhiza chilensis		4.0^{d}	0.0	0.0	50.0		8.0	17.0	28.0	
Penstemon cyananthus						36.0			0.0	
Penstemon humilis				1.0						
Penstemon rydbergii				30.5	65.5				52.0	59.0
Phacelia hastata	0.0			0.0		0.0				
Phlox longifolia		0.0		0.0	0.0	0.0			4.0	0.0
Picea engelmannii				0.0						
Polemonium caeruleum									0.0	
Polygonum aviculare		2.0		0.0					51.0	
Polygonum douglasii		2.7		0.0	0.0	0.0	0.2	2.0	1.6	0.0
Populus tremuloides^{c}	0.0	10.0		33.5						
Potentilla anserina	0.0	1.0		56.5	32.0	0.0			35.7	33.0^{d}
Ranunculus inameos		0.0	0.0	25.9^{d}	33.3	13.9	20.0	25.0	16.8	25.0
Ribes cereum^{c}						0.0				
Rosa woodsii^{c}		0.0								
Rudbeckia occidentalis					0.0					
Rumex salicifolius				100.0					0.0	
Senecio multilobatus						0.0	0.0	0.0	20.0	
Senecio serra	0.0	26.5		0.0	0.0	0.2	22.5		24.0	
Silene antirrhina										100.0
Smilacina stellata	0.5	43.0^{d}				2.0	46.0			
Solidago sparsiflora				97.5						
Stellaria jamesiana	0.0	0.2^{d}	0.0	9.6	9.0	3.1	0.6	0.0	4.8	0.0
Stellaria longifolia									0.0	
Stellaria media				0.0						
Swertia radiata									12.0	
Symphoricarpos oreophilus^{c}		4.2^{d}		1.5	0.0				0.0	
Taraxacum officinale		0.0	0.0	15.8	67.0	0.0	0.0		13.3	7.0
Thalictrum fendleri		4.0	0.0	12.5	9.0	0.0	0.0			
Tragopogon dubius						33.3	0.0			
Unknown annual forb						0.0				
Unknown forbs	0.3	0.2	0.0	0.0^{d}	0.0	0.0				
Urtica dioica						0.0	0.0			
Valeriana acutiloba				100.0						
Valeriana occidentalis					0.0	8.0				
Vicia americana	0.3	0.2	0.0	23.2	38.3	1.6	4.0	4.5	23.6	35.5
Viola nephrophylla									0.0	
Viola nuttallii	0.0	17.8		10.2^{d}	29.5	1.1	3.0	20.0	13.0	
Viola purpurea						0.0	0.0		0.0	
Grasses										
Agrostis exarata									0.0	
Bromus anomalus				33.0		0.0			16.7^{d}	34.0
Bromus carinatus	21.8	36.7	26.0	56.8	33.3	25.9	8.6	33.0	26.3	17.0
Bromus inermis		42.5		52.7^{d}	50.0	6.8			69.3	
Bromus tectorum		0.0								
Dactylis glomerata							21.0		40.0	
Deschampsia caespitosa									3.0	
Elymus elymoides									0.0	
Elymus spicatus						7.0			35.0	
Elymus trachycaulus	10.0	19.0	0.0	26.9	59.5	19.7	7.4	36.5	18.8	15.3
Festuca ovina							25.0			
Festuca pratensis				67.0					62.5	
Hordeum brachyantherum									7.0	
Melica bulbosa	30.0	9.7	0.0	12.0^{b}	2.0	3.4	4.6	0.0	1.1	0.0
Poa fendleriana		21.0		2.5	0.0	0.0	78.0		19.1^{d}	43.5
Poa nervosa									0.3^{d}	0.0
Poa pratensis	10.7	7.4	14.0	12.2^{b}	25.0	6.1	1.9	20.0	2.5	34.0
Poa secunda						24.0			0.0	
Stipa comata									100.0	

(con.)

Table A2 (Con.)

Species	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
	Spring	Summer	Fall[a]	Summer	Fall	Spring	Summer	Fall[a]	Summer	Fall
	Mean									
Stipa lettermanii	3.0	16.8		21.8	41.9	4.8	2.4	19.0	25.1	33.0
Stipa nelsoni	3.0	9.8[d]	0.0	9.5	21.8	13.1	4.8	0.0	11.8[d]	24.0
Trisetum spicatum					0.0					
Sedges and rushes										
Carex aquatilis									32.0	
Carex douglasii						0.0				19.0
Carex egglestoni									17.5	
Carex hoodii	17.5	11.8	16.0	17.6	65.3	20.8	2.0	13.0	37.4	32.0
Carex microptera				20.0						
Carex occidentalis		50.0								
Carex petasata				9.0					28.0	
Carex sp.				0.0						
Carex stenophylla						0.0			1.0	
Carex vallicola				0.0		9.0			19.3	89.0
Juncus arcticus				0.0		5.0			0.0	
Browse										
Abies lasciocarpa M									0.0	
Amelanchier alnifolia M									100.0	
Artemisia cana M		5.5		0.0		0.0	0.0		1.5	0.0
Artemisia cana Y		0.0		0.0	0.0					
Artemisia tridentata M		0.0		0.0	0.0	0.0	0.0		0.0	25.0
Artemisia tridentata Y	1.0			0.0	2.7					
Chrysothamnus nauseosus M						50.0	9.0			
Chrysothamnus viscidiflorus M		0.0		6.3		0.0	0.0	44.0	36.6	85.5
Chrysothamnus viscidiflorus Y		1.3		0.0	100.0					
Eriogonum umbellatum M									100.0	100.0
Mahonia repens M									3.0	
Pachystima myrsinites M									0.0	
Pachystima myrsinites Y					100.0					
Picea engelmannii M									0.0	
Populus tremuloides M		100.0	0.0	0.0	43.0	1.2	59.8	82.0	58.9	100.0
Populus tremuloides Y		46.0	100.0	12.5	50.0					
Prunus virginiana M		100.0								
Pseudotsuga menziesii M					0.0				0.0	
Ribes cereum M					100.0	11.0	100.0		83.5	87.5
Ribes montigeneum M						50.0	76.7	34.0	36.7	0.0
Rosa woodsii M									100.0	
Salix wolfii Y							100.0			
Sambucus racemosa M				100.0	72.0	0.0	79.5	100.0	44.5	100.0
Sambucus racemosa Y			100.0	0.0						
Symphoricarpos oreophilus M		52.4		84.2	73.3					100.0
Symphoricarpos oreophilus Y		52.8			16.0					

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[a] These samples may represent combined use, as sheep had previously grazed here.

[b] Indicates two samples missing.

[c] Woody plants with a basal stem diameter ≤0.32 cm were considered to be forbs due to their small size and forb-like texture.

[d] Indicates one sample missing.

Table A3—Kulcynski's Similarity (Sim) Index of the use of summer and fall standing biomass (based on dry biomass ratio utilized by elk or domestic sheep to dry standing biomass) of forbs, grasses, sedges, and browse (1994 only) and percent use of standing biomass by elk and domestic sheep in 1993 and 1994. A value of zero (0.0) indicates that a species was present in elk or domestic sheep feeding sites but was not utilized. Browse standing biomass used based on the percent of available biomass utilized by elk or domestic sheep in 22.6-m^2 belt transects.

	1993 Summer			1993 Fall			1994 Summer			1994 Fall		
Species	Sim	Elk use	Sheep use	Sim	Elk^a use	Sheep use	Sim	Elk use	Sheep use	Sim	Elk^a use	Sheep use
	Percent											
Forbs												
Achillea millefolium	83.6	1.49	1.07	10.1	0.40	7.49	76.6	1.05	1.69^b	13.5	22.0	1.59
Agastache urticifolia	0.0		6.82	0.0		50.00						
Antennaria parvifolia							0.0		3.2			
Arabis drummondii	17.0	21.69	2.02				0.0	0.00	5.44			
Artemisia ludoviciana							0.0	4.46				
Artemisia michauxiana	0.0	3.26	0.0				89.3	1.6	1.29^b	70.6	42.50	23.20
Artemisia tridentata^c				0.0		0.16						
Aster chilensis	0.0		2.0									
Aster foliaceous	0.0	1.00	0.0				0.0		6.51			
Astragalus agrestis										0.0		20.00
Astragalus convularis							0.0		12.0			
Calochortus nuttallii	0.0	6.50	0.00									
Chenopodium fremontii	99.9	4.27	4.26	0.0		28.30	0.0	0.00	1.38^b	0.0	1.50	
Chrysothamnus viscidiflorus^c	0.0	0.19	0.00				0.0		0.08			
Clematis hirsutissima							0.0		23.1^b			
Crepis acuminata	0.0		9.80									
Delphinium nuttallianum	0.0		7.29									
Delphinium occidentale	0.0	0.0	11.00									
Descurainia californica	0.0	0.01	0.00	0.0	1.00		36.9	1.00	4.42			
Erigeron eatonii	0.0	1.01	0.00	0.0		27.50						
Erigeron elatior	0.0	2.20	0.00									
Erigeron speciosus							91.2	26.50	22.20			
Erigeron ursinus	0.0	0.00^d	1.80				0.0		6.05	0.0	18.00	
Fragaria vesca	0.0	0.00	3.96	0.0		4.92	99.5	4.70	4.75^b	0.0	0.00	0.60
Galium boreale	0.0		8.00				0.0	1.50				
Gentianella amarella							0.0	0.00	0.41			
Geranium viscosissimum	0.0	0.00	57.62				95.2	15.00	16.50	0.0	22.80	
Hackelia floribunda	51.0	3.29	9.62	0.0		15.70	0.0		20.20			
Lathyrus lanzwertii	73.3	1.54	2.66	0.0		28.18	71.4	1.87	3.37^b	0.0		15.4
Linum perenne	0.0	2.00										
Lupinus lepidus	0.0	7.50^d		0.0		1.30						
Lupinus sericeus	7.9	9.70	0.40				0.0	0.00	12.6^b	0.0		19.7
Mertensia arizonica	35.6	6.99	32.26	0.0		30.44	81.8	12.10	17.50^b	0.0	63.00	
Monolepis nuttalliana	0.0		8.00									
Nemophila breviflora							0.0		1.28			
Orthocarpus tolmei	60.5	3.00	1.30									
Osmorhiza chilensis	34.1	1.80	8.76	0.0	1.80		80.1	9.00	6.01	0.0	12.20	
Penstemon rydbergii	0.0		5.87	0.0		3.00	0.0		10.40	0.0		17.20
Phlox longifolia	0.0		1.00	0.0		12.00	0.0		1.46^b	0.0		12.8
Polygonum aviculare	0.0	3.00	0.00				0.0		1.96			
Polygonum douglasii	0.0	0.00^d	1.21				0.0	0.00	0.29^b			
Potentilla anserina	18.7	1.14	11.04	0.0		17.60	0.0		6.37^b	0.0		11.3
Ranunculus inamoenus	0.0	0.00	14.14	0.0		27.76	80.5	3.10	4.60^b			
Rudbeckia occidentalis				0.0		7.00						
Rumex salicifolius	0.0		92.00				0.0		2.91			
Senecio multilobatus							0.0	19.00				
Senecio serra	0.0	0.00	3.50				55.4	1.47	3.84			
Smilacina stellata							0.0	14.7				
Solidago sparsiflora	0.0		21.35									
Stellaria jamesiana	0.5	0.01	3.67	0.0		3.70	22.4	0.65	5.15			
Taraxacum officinale	0.0		2.54				0.0	0.00	6.47^b			
Thalictrum fendleriana	0.0	0.00	6.02	0.0	0.00	5.94						
Valeriana acutiloba	0.0		91.00									
Valeriana occidentalis				0.0		37.00						
Vicia americana	30.8	1.38	7.58	0.0		15.30	70.1	5.51	10.2^b	75.8	15.00	24.6
Viola nuttallii	66.9	2.19	4.36	0.0		10.70	56.5	2.80	7.11	0.0	4.50	

(con.)

Table A3 (Con.)

	1993 Summer			1993 Fall			1994 Summer			1994 Fall		
Species	**Sim**	**Elk use**	**Sheep use**	**Sim**	**Elk[a] use**	**Sheep use**	**Sim**	**Elk use**	**Sheep use**	**Sim**	**Elk[a] use**	**Sheep use**
						Percent						
Grasses												
Bromus anomalus	0.0		6.00				0.0		0.75			
Bromus carinatus	91.4	7.49	6.31	17.7	3.00	30.96	70.1	3.02	5.60[b]	32.3	16.10	3.10
Bromus inermis	68.8	15.82[d]	30.14	0.0		27.06	0.0		18.6[b]			
Dactylis glomerata							0.0	15.3	0.00			
Deschampsia caespitosa							0.0		3.84			
Elymus elymoides							0.0		11.3			
Elymus spicatus	0.0	5.00[d]					0.0		12.00			
Elymus trachycaulus	51.6	1.80	5.18	32.6	2.30	11.83	44.6	1.21	4.22[b]	70.0	21.90	11.80
Festuca ovina							0.0	0.30				
Festuca pratensis	0.0		8.50				0.0	22.0				
Hordeum brachyantherum							0.0		12.4			
Melica bulbosa	48.6	0.95	2.96	0.0	0.00	0.45	0.0	0.00	8.50			
Poa fendleriana	0.0		0.84	0.0		0.50	33.9	24.00	4.89	0.0		8.46
Poa nervosa							0.0		2.60			
Poa pratensis	70.9	2.93	5.33	23.9	1.40	10.30	27.5	7.77	1.24[b]	60.2	2.76	6.41
Stipa comata							0.0		19.9			
Stipa lettermanii	82.4	3.02[d]	4.31	0.0		15.61	20.3	0.76	6.74[b]	26.3	3.00	19.80
Stipa nelsoni	18.9	1.07	10.27	0.0		9.15	72.8	2.36	4.12[b]	0.0	0.00	7.18
Sedges												
Carex aquatilis							0.0	0.00	5.64			
Carex douglasii										0.0		10.4
Carex egglestoni							0.0	0.00	8.47			
Carex hoodii	87.0	5.30	6.89	0.0	0.00	21.31	10.1	0.46	8.64[b]	0.0		14.4
Carex microptera	0.0		0.60									
Carex petasata	0.0		19.00				0.0	0.00	10.4			
Carex sp.	0.0		2.00									
Carex stenophylla							0.0	0.00	0.20			
Carex vallicola							0.0	0.00	5.62	0.0		23.1
Browse												
Abies lasciocarpa							0.0		0.0			
Amelanchier alnifolia							0.0		11.0			
Artemisia cana							0.0	0.0	0.0	0.0		0.0
Artemisia tridentata							0.0	0.0	0.0	0.0		5.3
Chrysothamnus nauseosus							0.0	0.0				
Chrysothamnus viscidiflorus							0.0	0.0	3.0	34.7	3.0	14.3
Eriogonum umbellatum							0.0		19.5	0.0		3.0
Mahonia repens							0.0		0.0			
Pachystima myrsinites							0.0		0.0			
Picea engelmannii							0.0		0.0			
Populus tremuloides							94.0	13.3	11.8	32.0	21.0	4.0
Psuedotsuga menziesii							0.0		0.0			
Ribes cereum							33.3	1.0	5.0	0.0		15.0
Ribes montigeneum							80.0	0.3	0.2	0.0	2.0	0.0
Rosa woodsii							0.0		13.0			
Salix wolfii							0.0		3.0			
Sambucus racemosa							52.5	9.0	25.3	40.7	12.0	47.0
Symphoricarpos oreophilus							97.3	5.5	5.8	93.0	3.8	3.3

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[a] Species listed under elk use for fall may have been subject to previous use by sheep.

[b] Species that may have been subject to previous use by elk at 1 to 3 sheep feeding site locations.

[c] Woody plants with a basal stem diameter ≤0.32 cm were considered to be forbs due to their small size and forb-like texture.

[d] Species that may have been subject to dual use by sheep at 1 elk feeding site location.

Table A4—Kulcynski's Similarity (Sim) Index (based on relative proportions of dry biomass in diets) of forbs, grasses, sedges, rushes, and browse (1994 only) in summer and fall diets of elk and domestic sheep, 1993 and 1994. The relative percent of each species in summer and fall elk and domestic sheep diets in 1993 and 1994. A zero (0.00) indicates that sampled species were present in feeding sites, and were not utilized, or contributed to less than 0.01 percent of seasonal diets.

	1993 Summer			1993 Fall			1994 Summer			1994 Fall		
Species	Sim	Elk diet	Sheep diet	Sim	Elk^{a} diet	Sheep diet	Sim	Elk diet	Sheep diet	Sim	Elk^{a} diet	Sheep diet
	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	*Percent*	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Forbs												
Achillea millefolium	88.9	0.24	0.30	27.0	1.09	0.17	70.7	0.29	0.53	84.8	0.38	0.28
Agastache urticifolia			0.22			13.10^{b}		0.00				
Agoseris glauca						0.00						
Androsace septentrionalis		0.00				0.00	0.0	0.00	0.00			0.00
Antennaria microphylla									0.00			
Antennaria parvifolia			0.00			0.00			0.20			
Arabis drummondii	1.9	1.04	0.01				0.0	0.00	0.23	21.7	0.74	0.09
Artemisia cana^{c}	0.0	0.00	0.00						0.00			
Artemisia ludoviciana		0.00						6.88^{d}				
Artemisia michauxiana	20.3	2.13^{d}	0.24				33.3	0.50	0.10	17.4	22.90^{d}	2.18^{b}
Artemisia tridentata^{c}			0.00			0.00			0.00			0.00
Aster chilensis			0.05									
Aster foliaceous		0.01							0.36			
Astragalus agrestis									0.00			0.59
Astragalus convallarius			0.00						0.05			
Calochortus nuttallii		0.02										
Chenopodium fremontii	76.9	0.16	0.10			3.11^{b}	0.0	0.00	0.01		0.03	
Chrysothamnus viscidiflorus^{c}	0.0	0.02	0.00						0.00			
Clematis hirsutissima			0.00						0.88^{b}			
Collomia debilis								0.00				
Collomia linearis						0.00			0.00			
Crepis acuminata			0.07									
Delphinium nuttallianum			0.34									
Delphinium occidentale	0.0	0.00	0.04									
Descurainia californica	0.0	0.00	0.00		0.94		57.1	0.05	0.02			
Draba crassifolia			0.00									
Erigeron eatonii		0.07				1.22						
Erigeron elatior		0.34										
Erigeron speciosus							45.0	1.93^{d}	0.56			
Erigeron ursinus	0.0	0.00	0.00			0.00			0.44		0.26	
Euphorbia brachycera								0.00				
Fragaria vesca	0.0	0.00	0.89			0.59	70.3	1.07^{e}	0.58^{e}	0.0	0.00	0.03
Fritillaria atropurpurea		0.00										
Galium aparine		0.00										
Galium bifolium			0.00						0.00			
Galium boreale			0.38					0.05				
Gentianella amarella							0.0	0.00	0.00			
Geranium viscosissimum	0.0	0.00	6.90^{b}				68.2	0.29	0.15		0.64	
Hackelia floribunda	4.0	0.99	0.02			0.02			0.22			0.00
Heracleum lanatum								0.00				
Hydrophyllum capitatum							0.0	0.00	0.00			
Lathyrus lanzwertii	44.1	1.38	0.39			3.31^{b}	83.9	0.52	0.72			0.66
Lepidium densiflorum							0.0	0.00	0.00			
Linum perenne		0.00										
Lupinus lepidus		0.02				0.00						
Lupinus sericeus	11.6	2.43^{d}	0.15				0.0	0.00	3.62^{b}			2.52^{b}
Mertensia arizonica	75.0	40.45^{d}	24.26^{b}			6.17^{b}	47.6	20.37^{d}	6.37^{b}		7.77^{d}	
Monolepis nuttalliana			0.04									
Nemophila breviflora									0.01			
Orthocarpus tolmei	50.0	0.01	0.03									
Osmorhiza chilensis	41.7	0.19	0.05		1.30		11.5	0.82	0.05		0.73	
Penstemon humilis			0.00									
Penstemon rydbergii			7.00^{b}			0.27			0.22			1.28^{e}
Phacelia hastata			0.00									
Phlox longifolia			0.00			0.06			0.07			0.15
Polemonium caeruleum									0.00			

(con.)

Table A4 (Con.)

Species	1993 Summer			1993 Fall			1994 Summer			1994 Fall		
	Sim	Elk diet	Sheep diet	Sim	Elk[a] diet	Sheep diet	Sim	Elk diet	Sheep diet	Sim	Elk[a] diet	Sheep diet
	Percent											
Polygonum aviculare	0.0	0.01	0.0						0.02			
Polygonum douglasii	0.0	0.00	0.01				0.0	0.00	0.02	0.0	0.00	0.00
Populus tremuloides		0.00										
Potentilla anserina	49.1	0.27	0.83			1.21			0.33			0.26
Ranunculus inamoenus	0.0	0.00	0.42			1.07	45.5	0.05	0.17			
Rudbeckia occidentalis						0.03						
Rumex salicifolius			2.85[b]						0.03			
Senecio multilobatus								0.07				
Senecio serra	0.0	0.00	0.16			0.00	12.0	1.10[e]	0.07[e]			
Silene antirrhina												0.00
Smilacina stellata		0.00						1.60[d]				
Solidago sparsiflora			0.45									
Stellaria jamesiana	0.0	0.00	0.07			0.03	90.9	0.05	0.06			
Swertia radiata									0.00			
Symphoricarpos oreophilus[c]	0.0	0.00	0.00									
Taraxacum officinale			0.03				0.0	0.00	0.05			0.00
Thalictrum fendleriana	0.0	0.00	0.93	0.0	0.00	0.74		0.00				
Tragopogon dubius								0.00				
Urtica dioica								0.00				
Valeriana acutiloba			3.76[b]									
Valeriana occidentalis						0.78						
Vicia americana	59.0	0.36	0.86			1.40	52.9	0.36	1.00[b]	58.3	0.21	0.51
Viola nephrophylla									0.00			
Viola nuttallii	80.0	0.20	0.30			0.03	75.9	0.18	0.11		0.08	
Viola purpurea								0.00	0.00			
Grasses												
Agrostis exarata									0.00			
Bromus anomalus			0.13						0.02			0.00
Bromus carinatus	42.2	29.24[d]	7.83[b]	16.7	66.67[d]	6.07[b]	50.1	8.88[d]	2.97[b]	12.9	9.43[d]	0.65
Bromus inermis	75.5	10.92[d]	18.00[d]			17.21[b]			21.92[b]			
Dactylis glomerata							0.0	0.33	0.00			
Deschampsia caespitosa									0.35			
Elymus elymoides									0.04			
Elymus spicatus		0.01							0.81			
Elymus trachycaulus	74.3	2.07[d]	3.50[b]	22.5	21.51[d]	2.73[b]	94.7	2.34[d]	2.60[b]	40.9	23.10[d]	5.94[b]
Festuca ovina								0.01				
Festuca pratensis			1.17						4.78[b]			
Hordeum brachyantherum									0.35			
Melica bulbosa	97.0	0.81	0.86	0.0	0.00	0.03	0.0	0.00	1.07[b]		0.00	
Poa fendleriana			0.02			0.01	35.2	4.03[d]	0.86			2.02[b]
Poa nervosa									0.04			0.00
Poa pratensis	98.1	1.52	1.58[b]	12.7	8.40[d]	0.57	12.9	0.87	0.06	92.3	0.30	0.35
Poa secunda									0.00			
Stipa comata									1.60[b]			
Stipa lettermanii	54.1	1.63	4.40[b]			15.55[b]	18.8	0.81	7.79[b]	2.5	0.27	21.18[b]
Stipa nelsoni	15.7	0.40	4.68[b]			1.48	61.7	4.60[d]	2.05[b]	0.0	0.00	1.07[e]
Sedges and rushes												
Carex aquatilis									2.02[b]			
Carex douglasii												1.96[b]
Carex egglestoni									1.31[b]			
Carex hoodii	69.7	3.07[d]	5.74[b]	0.0	0.00	23.02[b]	14.3	0.43	5.57[b]			1.30[e]
Carex microptera			0.04									
Carex occidentalis		0.00										
Carex petasata			0.15						1.96[b]			
Carex sp.			0.02									
Carex stenophylla									0.00			
Carex vallicola			0.00						0.45			3.25[b]
Juncus arcticus			0.00						0.00			

(con.)

Table A4 (Con.)

	1993 Summer			1993 Fall			1994 Summer			1994 Fall		
Species	Sim	Elk diet	Sheep diet	Sim	Elk[a] diet	Sheep diet	Sim	Elk diet	Sheep diet	Sim	Elk[a] diet	Sheep diet
	Percent											
Browse												
Amelanchier alnifolia									1.70[b]			
Artemisia tridentata												1.81
Chrysothamnus viscidiflorus									2.39[b]	90.3	5.28[d]	6.41[b]
Eriogonum umbellatum									0.07			
Populus tremuloides							46.0	10.18[d]	3.04[b]	89.3	4.08[d]	3.29[b]
Ribes cereum							40.2	1.03	4.09[b]			3.62[b]
Ribes montigeneum									0.72			
Salix wolfii								16.45[d]				
Sambucus racemosa							80.3	0.51	0.76	23.7	3.60	26.79[b]
Symphoricarpos oreophilus							91.7	13.37[d]	11.33[b]	73.9	20.18[d]	11.83[b]

[a] Species listed under elk use in fall and in other elk feeding sites that may have been subject to previous use by sheep.

[b] These species composed at least 90 percent of sheep diets during the respective seasons and were subjected to nutritional analyses. In 1993, 12 species composed 90.5 percent of sheep diets in summer, and in fall 1993, nine species composed 90.3 percent of sheep diets. In summer 1994, 21 species composed 90.1 percent of sheep diets, and in fall, 12 species composed 91.0 percent of sheep diets.

[c] Woody plants with a basal stem diameter ≤0.32 cm were considered to be forbs due to their small size and forb-like texture.

[d] These species composed at least 90 percent of elk diets during the respective seasons and were subjected to nutritional analyses. In summer 1993, seven species composed 90.3 percent of elk diets, and in fall 1993, three species composed 96.6 percent of elk diets. In 1994, 11 species composed 90.6 percent of elk summer diets, and in fall, seven species composed 92.7 percent of elk diets.

[e] These species composed at least 90 percent of 1994 elk or sheep herbaceous diets but not diets including browse and were subjected to nutritional analyses. These species can be used to compare with the 1993 diet, which was only sampled for herbaceous species.

Table A5—Ivlev's Electivity Index of seasonal forb, grass, sedge, and rush preferences of elk and domestic sheep in 1993 and 1994. This index calculated relative to all herbaceous species. Preference values are from 0.00 to +1.00, and avoidance values are from 0.00 to –1.00.

	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
Species	Spring	Summer	Fall[a]	Summer	Fall	Spring	Summer	Fall[a]	Summer	Fall
	Mean									
Forbs										
Achillea millefolium	–1.00	–0.87	–0.51	–0.67	–0.34	–0.76	–0.68	–0.45	–0.60	–0.31
Agastache urticifolia	–0.83			+0.48	+0.19	–1.00	–1.00			
Agoseris glauca				–1.00		–1.00				
Androsace septentrionalis		–1.00			–0.50	–1.00	–1.00		–1.00	–1.00
Antennaria microphylla									–1.00	
Antennaria parvifolia				–1.00	–1.00				–0.65	
Arabis drummondii		–0.23		–0.59		–0.81	–1.00	+0.09	–0.65	–0.66
Artemisia cana[b]		–1.00		–1.00		–1.00			–1.00	
Artemisia dracunculus						–1.00				
Artemisia ludoviciana		–1.00					–0.10			
Artemisia michauxiana	–1.00	–0.35				+0.18	+0.44	+0.40	–0.46	+0.41
Artemisia tridentata[b]				–1.00	–0.98				–1.00	–1.00
Aster chilensis				–0.62		–1.00				
Aster foliaceous	+0.06	–0.65							+0.02	
Astragalus agrestis									–1.00	+0.27
Astragalus convallarius				–1.00					–0.15	
Calochortus nuttallii		+0.57				–0.25				
Chenopodium capitatum						–0.44				
Chenopodium fremontii		–0.39		–0.56	–0.09	–1.00	–1.00	–0.85	–0.62	
Chrysothamnus viscidiflorus[b]		–0.93		–1.00		–1.00			–0.99	
Clematis hirsutissima				–1.00		–0.37			+0.32	
Collomia debilis							–1.00			
Collomia linearis					–1.00				–1.00	
Crepis acuminata				–0.40						
Delphinium nuttallianum	+0.28			–0.59		–0.56				
Delphinium occidentale		–1.00		+0.44		–1.00				
Descurainia californica	–1.00	–0.98	–0.11	–1.00		–0.46	–0.76		+0.46	
Draba crassifolia				–1.00						
Erigeron eatonii		–0.70			+0.39					
Erigeron elatior		+0.27								
Erigeron speciosus							+0.82		+0.35	
Erigeron ursinus		–1.00		–0.73	–1.00	–1.00		–0.01	–0.10	
Euphorbia brachycera							–1.00			
Fragaria vesca	–1.00	–1.00		–0.39	–0.61	–0.86	–0.02	–1.00	–0.29	–0.88
Fritillaria atropurpurea		–1.00				–1.00				
Galium aparine		–1.00		–1.00						
Galium bifolium									–1.00	
Galium boreale				+0.33			+0.20			
Gentianella amarella							–1.00		–0.92	
Geranium viscosissimum	–0.57	–1.00		+0.51		–0.33	–0.03	–0.09	–0.37	
Hackelia floribunda		–0.21		+0.13	–0.14	–1.00			+0.30	–1.00
Heracleum lanatum							–1.00			
Hydrophyllum capitatum							–1.00		–1.00	
Lathyrus lanzwertii		–0.82		–0.71	+0.02	–0.18	–0.31		–0.34	+0.23
Lepidium densiflorum						–1.00	–1.00		–1.00	
Lesquerella alpina						–1.00				
Linum perenne		+0.06				–1.00				
Lomatium graveolens						–1.00				
Lupinus lepidus		–0.41			–0.81	–1.00				
Lupinus sericeus	–1.00	+0.36		–0.94		–0.74	–1.00		+0.16	–0.04
Mertensia arizonica	+0.23	–0.02		+0.57	+0.33	–0.21	+0.23	+0.39	+0.26	
Mertensia brevistyla						–1.00				
Monolepis nuttalliana				–0.60						
Nemophila breviflora						–0.77			+0.35	
Orthocarpus tolmei		–0.20		+0.05		–1.00				
Osmorhiza chilensis		–0.58	+0.17	+0.34			+0.63	–0.38	+0.35	
Penstemon cyananthus						+0.26				
Penstemon humilis				–1.00						

(con.)

Table A5 (Con.)

Species	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
	Spring	Summer	Fall[a]	Summer	Fall	Spring	Summer	Fall[a]	Summer	Fall
	Mean									
Penstemon rydbergii				–0.34	–0.76				+0.05	+0.19
Phacelia hastata						–1.00				
Phlox longifolia				–0.85	–0.47	–1.00			–0.93	+0.05
Polemonium caeruleum									–1.00	
Polygonum aviculare		+0.26		–1.00					–0.79	
Polygonum douglasii		–1.00		–0.85		–1.00	–1.00	–1.00	–0.97	–1.00
Populus tremuloides[b]		–1.00								
Potentilla anserina	–1.00	–0.73		+0.10	–0.12	–0.28			–0.28	+0.36
Ranunculus inameos		–1.00		–0.12	–0.35	–0.44	–0.27		–0.34	
Rudbeckia occidentalis					–0.66					
Rumex salicifolius				+0.49					–0.34	
Senecio multilobatus						–1.00	+0.59			
Senecio serra	–1.00	–1.00		+0.49	–1.00	–1.00	–0.26		–0.21	
Silene antirrhina		–								–1.00
Smilacina stellata	–1.00	–1.00				–1.00	+0.02			
Solidago sparsiflora				+0.68						
Stellaria jamesiana	–1.00	–0.97		–0.64	–0.80	–0.65	–0.56		–0.46	
Swertia radiata									–1.00	
Symphoricarpos oreophilus[b]		–1.00		–1.00						
Taraxacum officinale				–0.56		–0.65	–1.00		–0.25	–1.00
Thalictrum fendleri		–1.00	–1.00	+0.16	–0.68		–1.00			
Tragopogon dubius						+0.56	–1.00			
Urtica dioica						–1.00	–1.00			
Unknown forb	–1.00									
Valeriana acutiloba				+0.48						
Valeriana occidentalis					+0.28	+0.15				
Vicia americana	–1.00	–0.87		–0.12	–0.11	–0.71	–0.63	–0.29	–0.30	+0.65
Viola nephrophylla									–1.00	
Viola nuttallii	–1.00	–0.64		–0.38	–0.06	–0.69	+0.15	–0.72	+0.59	
Viola purpurea						–1.00				
Grasses										
Agrostis exarata									–1.00	
Bromus anomalus				+0.15		–1.00			–0.76	–1.00
Bromus carinatus	+0.17	–0.03	+0.42	–0.28	–0.45	–0.17	–0.14	–0.19	–0.18	–0.51
Bromus inermis		+0.24		+0.32	+0.25	+0.34			+0.19	
Dactylis glomerata							+0.40		–1.00	
Deschampsia caespitosa									–0.21	
Elymus elymoides									–0.18	
Elymus spicatus		–0.56				+0.23			–0.50	
Elymus trachycaulus	–0.52	–0.38	+0.29	–0.16	–0.42	–0.06	–0.53	–0.21	–0.46	–0.25
Festuca ovina							–0.91			
Festuca pratensis				+0.32					+0.18	
Hordeum brachyantherum									+0.35	
Melica bulbosa	+0.36	–0.56	–1.00	–0.77	–0.92	–0.59	–1.00	–1.00	–0.59	
Poa fendleriana				–0.67	–0.96	–1.00	+0.66		–0.37	+0.10
Poa nervosa									–0.64	–1.00
Poa pratensis	–0.79	–0.37	+0.06	–0.61	–0.34	–0.59	–0.15	–0.67	–0.64	+0.13
Poa secunda						+0.09			–1.00	
Stipa comata									+0.10	
Stipa lettermanii	–0.74	–0.31		–0.27	–0.42	–0.78	–0.64	–0.72	–0.31	+0.06
Stipa nelsoni	+0.03	–0.55		–0.46	–0.20	–0.52	–0.46	–1.00	–0.42	–0.65
Sedges and rushes										
Carex aquatilis									–0.03	
Carex douglasii						–1.00				–0.06
Carex egglestoni									+0.17	
Carex hoodii	–0.08	–0.04	–1.00	–0.39	–0.12	–0.43	–0.51		–0.21	+0.17
Carex microptera				–0.69						
Carex occidentalis		–1.00								
Carex petasata				+0.38					–0.03	
Carex sp.				–0.37						

(con.)

Table A5 (Con.)

Species	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
	Spring	Summer	Fall[a]	Summer	Fall	Spring	Summer	Fall[a]	Summer	Fall
	Mean									
Carex stenophylla						–1.00			–0.67	
Carex vallicola				–1.00		–0.81			–0.36	+0.04
Juncus arcticus				–1.00		+0.12			–1.00	

[a] Elk feeding sites in fall were subject to previous use by sheep.
[b] Woody plants with a basal stem diameter ≤0.32 cm were considered to be forbs due to their small size and forb-like texture.

Table A6—Ivlev's Electivity Index of seasonal forb, grass, sedge, rush, and browse preferences of elk and domestic sheep, 1994. This index calculated relative to all herbaceous and woody species. Preference values are from 0.00 to +1.00, and avoidance values are from 0.00 to –1.00.

Species	1994 Elk			1994 Sheep	
	Spring	Summer	Fall[a]	Summer	Fall[a]
	Mean				
Forbs					
Achillea millefolium	–0.76	–0.70	–0.12	–0.57	–0.44
Agastache urticifolia	–1.00	–1.00			
Agoseris glauca	–1.00				
Androsace septentrionalis	–1.00	–1.00		–1.00	–1.00
Antennaria parvifolia				–0.65	
Arabis drummondii	–0.81	–1.00	+0.42	–0.54	–0.47
Artemisia cana[b]	–1.00			–1.00	
Artemisia dracunculus	–1.00				
Artemisia ludoviciana		–0.07			
Artemisia michauxiana	+0.18	+0.09	+0.65	–0.49	+0.27
Artemisia tridentata[b]				–1.00	–1.00
Aster chilensis	–1.00				
Aster foliaceous				+0.02	
Astragalus agrestis				–1.00	+0.22
Astragalus convallarius				–0.15	
Calochortus nuttallii	–0.25				
Chenopodium capitatum	–0.44				
Chenopodium fremontii	–1.00	–1.00	–0.71	–0.48	
Chrysothamnus viscidiflorus[b]	–1.00			–0.99	
Clematis hirsutissima	–0.37			+0.61	
Collomia debilis		–1.00			
Collomia linearis				–1.00	
Delphinium nuttallianum	–0.56				
Delphinium occidentale	–1.00				
Descurainia californica	–0.46	–0.77		+0.27	
Erigeron speciosus		+0.79		+0.47	
Erigeron ursinus	–1.00		+0.34	–0.05	
Euphorbia brachycera		–1.00			
Fragaria vesca	–0.86	+0.22	–1.00	–0.23	–0.91
Fritillaria atropurpurea	–1.00				
Galium bifolium				–1.00	
Galium boreale		–0.24			
Gentianella amarella		–1.00		–0.92	
Geranium viscosissimum	–0.33	–0.06	+0.51	–0.36	
Hackelia floribunda	–1.00			+0.77	–1.00
Heracleum lanatum		–1.00			
Hydrophyllum capitatum		–1.00		–1.00	
Lathyrus lanzwertii	–0.18	–0.35		–0.12	+0.08

(con.)

Table A6 (Con.)

Species	1994 Elk			1994 Sheep	
	Spring	Summer	Fall[a]	Summer	Fall[a]
	Mean				
Lepidium densiflorum	–1.00	–1.00		–1.00	
Lesquerella alpina	–1.00				
Linum perenne	–1.00				
Lomatium graveolens	–1.00				
Lupinus lepidus	–1.00				
Lupinus sericeus	–0.74	–1.00		+0.19	+0.57
Mertensia arizonica	–0.21	+0.25	+0.79	+0.40	
Mertensia brevistyla	–1.00				
Nemophila breviflora	–0.77			–0.32	
Orthocarpus tolmei	–1.00				
Osmorhiza chilensis		+0.72	+0.24	+0.37	
Penstemon cyananthus	+0.25				
Penstemon rydbergii				+0.05	+0.15
Phacelia hastata	–1.00				
Phlox longifolia	–1.00			–0.84	0.00
Polemonium caeruleum				–1.00	
Polygonum aviculare				–0.79	
Polygonum douglasii	–1.00	–1.00	–1.00	–0.96	–1.00
Potentilla anserina	–0.28			–0.30	+0.65
Ranunculus inameos	–0.44	–0.27		–0.38	
Rumex salicifolius				–0.34	
Senecio multilobatus	–1.00	+0.72			
Senecio serra	–1.00	–0.36		–0.21	
Silene antirrhina					–1.00
Smilacina stellata	–1.00	+0.02			
Stellaria jamesiana	–0.65	–0.52		–0.28	
Swertia radiata				–1.00	
Taraxacum officinale	–0.65	–1.00		–0.21	–1.00
Thalictrum fendleri		–1.00			
Tragopogon dubuis	+0.56	–1.00			
Urtica dioica	–1.00	–1.00			
Valeriana occidentalis	+0.15				
Vicia americana	–0.71	–0.66	+0.34	–0.16	+0.82
Viola nephrophylla				–1.00	
Viola nuttallii	–0.69	+0.32	–0.25	+0.47	
Viola purpurea	–1.00				
Grasses					
Agrostis exarata				–1.00	
Bromus anomalus	–1.00			–0.74	–1.00
Bromus carinatus	–0.17	–0.17	+0.28	–0.08	–0.62
Bromus inermis	+0.34			+0.30	
Dactylis glomerata		+0.27		–1.00	
Deschampsia caespitosa				–0.21	
Elymus elymoides				–0.18	
Elymus spicatus	+0.23			–0.12	
Elymus trachycaulus	–0.06	–0.58	+0.24	–0.34	–0.01
Festuca ovina		–0.93			
Festuca pratensis				+0.22	
Hordeum brachyantherum				+0.35	
Melica bulbosa	–0.59	–1.00	–1.00	–0.48	
Poa fendleriana	–1.00	+0.64		–0.30	+0.26
Poa nervosa				–0.62	–1.00
Poa pratensis	–0.59	–0.15	–0.36	–0.60	–0.02
Poa secunda	+0.09			–1.00	

(con.)

Table A6 (Con.)

Species	1994 Elk			1994 Sheep	
	Spring	Summer	Fall[a]	Summer	Fall[a]
	- - - - - - - - - -	- - - - - - - - - -	*Mean*	- - - - - - - - - -	- - - - - - - - - -
Stipa comata				+0.10	
Stipa lettermanii	–0.78	–0.63	–0.49	–0.21	+0.24
Stipa nelsoni	–0.52	–0.49	–1.00	–0.34	–0.71
Sedges and rushes					
Carex aquatilis				–0.03	
Carex douglasii	–1.00				–0.10
Carex egglestoni				+0.30	
Carex hoodii	–0.43	–0.48		–0.12	+0.28
Carex petasata				+0.06	
Carex *stenophylla*	–1.00			–0.89	
Carex vallicola	–0.81			–0.15	+0.62
Juncus arcticus	+0.12			–1.00	
Browse					
Amelanchier alnifolia				+0.72	
Artemisia tridentata					+0.49
Chrysothamnus nauseosus	–1.00				
Chrysothamnus viscidiflorus			–0.49	–0.12	+0.48
Eriogonum umbellatum				+0.46	
Populus tremuloides		+0.53	+0.42	+0.26	–0.54
Ribes cereum		–0.49		–0.31	–0.41
Ribes montigeneum	–0.11			–0.50	
Salix wolfii		–0.01			
Sambucus racemosa		+0.93	+0.23	+0.62	+0.59
Symphoricarpos oreophilus	–0.23	–0.02	–0.43	–0.12	–0.17

[a] Elk feeding sites in fall were subject to previous use by sheep.

[b] Woody plants with a basal stem diameter ≤0.32 cm were considered to be forbs due to their small size and forb-like texture.

Table A7—Ivlev's Electivity Index of seasonal forb, grass, sedge, and browse preferences of elk and domestic sheep in aspen communities, 1994. This index calculated relative to all herbaceous and woody species. Preference values from 0.00 to +1.00, and avoidance values from 0.00 to –1.00.

Species	1994 Elk			1994 Sheep
	Spring	Summer	Fall[a]	Summer
	- - - - - - - - - -	- - - - - - - - - -	*Mean*	- - - - - - - - - -
Forbs				
Achillea millefolium	–0.91			–0.32
Agastache urticifolia	–1.00	–1.00		
Arabis drummondii		–1.00		–0.00
Artemisia ludoviciana		+0.14		
Artemisia michauxiana		+0.49		
Astragalus convallarius				–0.15
Chenopodium fremontii	–1.00	–1.00		
Collomia linearis				–1.00
Delphinium nuttallianum	+0.76			
Delphinium occidentale	–1.00			
Descurainia californica	–0.42			+0.27
Erigeron ursinus	–1.00			
Fragaria vesca	–1.00	–1.00	–1.00	
Fritillaria atropurpurea	–1.00			
Galium bifolium				–1.00

(con.)

Table A7 (Con.)

Species	1994 Elk			1994 Sheep
	Spring	Summer	Fall[a]	Summer
	Mean			
Geranium viscosissimum	–0.19	–0.25	+0.51	
Hackelia floribunda	–1.00			
Heracleum lanatum		–1.00		
Hydrophyllum capitatum		–1.00		–1.00
Lathyrus lanzwertii	+0.30	–0.17		
Lepidium densiflorum	–1.00	–1.00		
Lupinus lepidus	–1.00			
Mertensia arizonica	–0.33	+0.09	+0.79	+0.69
Nemophila breviflora	–0.77			–0.32
Osmorhiza chilensis		+0.48	+0.24	+0.37
Phlox longifolia	–1.00			
Polygonum aviculare				–0.79
Polygonum douglasii	–1.00			–0.96
Potentilla anserina	+0.06			
Ranunculus inameos	–0.56			+0.41
Senecio serra	–1.00			
Stellaria jamesiana	–0.53	–0.53		–0.91
Taraxacum officinale	–1.00			–0.27
Thalictrum fendleri		–1.00		
Tragopogon dubuis	+0.56	–1.00		
Valeriana occidentalis	+0.15			
Vicia americana	–0.46	–0.33	+0.34	+0.17
Viola nuttallii	–0.70	+0.04	–0.25	+0.47
Grasses				
Bromus carinatus	–0.16	+0.01	+0.51	–0.81
Bromus inermis	+0.76			
Elymus elymoides				–0.18
Elymus trachycaulus	+0.07	–0.62	+0.58	–0.43
Festuca pratensis				+0.17
Melica bulbosa	–0.18	–1.00		–1.00
Poa fendleriana		+0.64		–0.38
Poa pratensis	–0.69	+0.03	+0.29	–1.00
Stipa comata				+0.10
Stipa lettermanii	–1.00	–0.72		–0.06
Stipa nelsoni	–0.21	–0.91	–1.00	+0.16
Sedges				
Carex egglestoni				–0.15
Carex hoodii	–0.06	–0.17		–1.00
Browse				
Chrysothamnus viscidiflorus				+0.02
Populus tremuloides		+0.70	+0.55	+0.35
Sambucus racemosa		+0.58	+0.23	+0.59
Symphoricarpos oreophilus	+0.53	–0.58	–0.66	+0.26

[a] Elk feeding sites in fall were subject to previous use by sheep.

Appendix B: Nutritional Analyses of Major Forage Species; and Water Content and Poisonous Properties of Plant Species

Table B1—Nutritional analyses (ppm = parts per millon) results were derived (CP = crude protein[a], ADF = acid detergent fiber[b], TNC = total nonstructural carbohydrates[c], Ca = calcium, K = potassium, Mg = magnesium, P = phosphorous, Cu = copper, Fe = iron, Mn = manganese, Na = sodium, and Zn = zinc) from testing those species that composed at least 90 percent of seasonal (Sp = spring, Su = summer, F = fall) elk[d] and/or domestic sheep[d] diets, 1993 and 1994. Herbaceous species were analyzed in 1993 and 1994. Browse species were analyzed in 1994 only.

Species	CP	ADF	TNC	Ca	K	Mg	P	Cu	Fe	Mn	Na	Zn
	Percent							ppm				
1993												
Forbs												
Agastache urticifolia Su[e]	9.4	29.4	17.2	1.47	2.42	0.35	0.38	11	216	46	131	82
Agastache urticifolia F	4.5	49.3	14.9	0.59	2.10	0.13	0.11	8	74	11	342	49
Artemisia michauxiana Su	24.3	25.6	19.5	1.49	2.23	0.37	0.14	8	45	65	550	42
Aster foliaceous Sp[e]	23.6	12.5	16.1	0.76	4.70	0.23	0.70	18	78	51	70	54
Chenopodium fremontii F	6.5	42.9	17.2	0.53	3.40	0.32	0.14	4	127	64	54	50
Geranium viscossisimum Su	10.3	22.2	27.1	1.15	2.13	0.21	0.44	6	187	23	93	38
Lathyrus lanzwertii F	9.8	41.2	12.1	1.38	1.63	0.19	0.08	6	139	42	119	27
Lupinus sericeus Sp[e]	28.2	20.1	12.0	1.17	1.80	0.29	0.34	11	106	61	276	43
Lupinus sericeus Su	13.3	27.9	14.9	1.76	1.42	0.36	0.12	7	173	55	72	22
Mertensia arizonica Sp	21.6	22.6	11.3	0.97	6.13	0.20	0.50	20	131	46	106	35
Mertensia arizonica Su	4.4	46.9	13.7	1.63	2.41	0.19	0.35	12	89	29	202	45
Mertensia arizonica F	3.6	42.4	12.7	2.03	2.93	0.19	0.31	11	99	27	255	31
Penstemon rydbergii Su	11.3	34.7	15.7	1.32	3.08	0.31	0.29	15	151	27	218	28
Penstemon rydbergii F[e]	6.2	36.4	18.5	1.13	1.22	0.25	0.20	16	84	21	330	24
Rumex salicifolius Su	14.8											
Valeriana acutiloba Su	12.6		15.5									
Grasses												
Bromus carinatus Sp	21.8	24.4	13.7	0.40	3.47	0.16	0.41	13	88	52	79	29
Bromus carinatus Su	10.9	33.8	14.2	0.25	2.53	0.12	0.25	11	63	50	195	29
Bromus carinatus F	10.3	41.0	13.3	0.42	2.17	0.12	0.20	11	182	95	280	33
Bromus inermis Su	28.9	21.4	13.7	0.38	4.38	0.17	0.44	18	123	80	112	39
Bromus inermis F	6.3	33.8	15.3	0.54	1.50	0.10	0.10	8	251	154	265	26
Elymus trachycaulus Sp[e]	25.3	23.4	16.2	0.41	2.75	0.14	0.39	14	134	49	109	31
Elymus trachycaulus Su	13.6	32.0	13.1	0.47	1.98	0.14	0.24	10	181	49	141	30
Elymus trachycaulus F	8.2	42.6	10.4	0.35	1.40	0.12	0.18	8	130	74	111	29
Festuca pratensis Su[e]	11.0	35.5	17.3	0.45	2.15	0.11	0.20	5	142	113	63	32
Poa pratensis Su	15.6	23.5	27.0	0.26	2.31	0.12	0.35	8	90	40	98	36
Poa pratensis F	10.8	25.9	29.3	0.68	1.95	0.23	0.24	6	91	57	50	36
Stipa lettermanii Sp	22.3	27.7	13.6	0.34	1.90	0.11	0.36	11	109	44	88	37
Stipa lettermanii Su	9.9	34.6	12.9	0.28	1.17	0.08	0.20	9	110	38	235	23
Stipa lettermanii F	7.6	36.3	13.3	0.34	0.80	0.08	0.18	8	121	25	247	22
Stipa nelsoni Su	12.2	33.0	15.2	0.27	1.63	0.08	0.25	11	91	21	263	28
Stipa nelsoni F[e]	12.3	1.1	13.1	0.56	1.20	0.12	0.19	10	271	56	350	26
Sedges												
Carex hoodii Sp	21.7	27.4	11.2	0.38	2.53	0.14	0.40	17	140	47	63	28
Carex hoodii Su	9.9	30.7	19.5	0.46	2.68	0.14	0.22	9	173	60	219	23
Carex hoodii F	5.3	39.8	13.2	0.40	1.80	0.13	0.16	7	228	61	115	24
1994												
Forbs												
Artemisia ludoviciana Su	13.5	24.0	15.8	1.25	3.07	0.26	0.11	13	59	49	43	47
Artemisia michauxiana F	6.6	42.6	14.3	1.16	1.30	0.25	0.09	4	1,033	76	39	34
Clematis hirsutissima Sp	14.1	25.4	26.4	0.99	2.03	0.17	0.26	9	116	31	38	64
Clematis hirsutissima Su	6.2	47.5	14.2	1.26	0.81	0.22	0.07	5	275	46	69	30
Erigeron speciosus Su	11.8	29.7	13.9	1.24	3.94	0.18	0.07	8	82	39	40	30
Fragaria vesca Su[e]	9.0	21.5	20.5	1.14	1.80	0.45	0.38	5	179	42	32	30
Lupinus sericeus Su	10.9	36.3	13.1	1.07	1.53	0.22	0.14	6	140	30	59	40
Lupinus sericeus F	7.9	54.9	7.7	1.13	0.09	0.27	0.05	1	188	27	33	21

(con.)

Table B1 (Con.)

Species	CP	ADF	TNC	Ca	K	Mg	P	Cu	Fe	Mn	Na	Zn
				Percent						ppm		
Mertensia arizonica Sp	16.9	21.0	15.7	1.08	5.83	0.23	0.57	9	51	31	47	26
Mertensia arizonica Su	4.0	38.1	19.7	1.50	3.05	0.17	0.19	6	123	11	45	29
Mertensia arizonica F	6.3	27.8	7.0	1.67	0.28	0.19	0.11	6	113	37	26	39
Penstemon rydbergii F[e]	9.1		20.0	1.00	1.02	0.16	0.11	9	251	33	64	33
Potentilla anserina Sp	18.7	22.1	18.3	1.25	1.98	0.32	0.33	5	508	95	64	54
Senecio serra Su[e]	5.9	41.2	11.1	2.13	2.03	0.35	0.04	8	50	63	21	24
Smilacina stellata Su	16.6	19.7	19.8	1.34	3.10	0.26	0.43	4	129	60	24	30
Vicia americana Su	6.7	36.9	12.6	1.78	2.63	0.28	0.09	4	63	127	73	56
Grasses												
Bromus carinatus Sp	16.2	28.6	15.3	0.53	4.61	0.14	0.39	3	133	70	42	23
Bromus carinatus Su	7.9	36.4	15.6	0.50	2.30	0.12	0.17	4	57	62	45	27
Bromus carinatus F	8.3	43.2	9.8	0.50	0.75	0.10	0.12	3	75	76	61	40
Bromus inermis Sp	20.5	25.1	16.2	0.58	3.51	0.16	0.43	7	82	54	40	32
Bromus inermis Su	6.3	33.7	21.6	0.57	1.92	0.12	0.16	4	56	84	44	27
Elymus spicatus Sp	16.4	25.5	22.5	0.50	2.26	0.14	0.31	6	114	37	31	22
Elymus trachycaulus Sp	19.3	26.1	15.8	0.51	3.19	0.14	0.32	8	105	77	39	29
Elymus trachycaulus Su	9.6	33.9	16.9	0.35	2.21	0.09	0.23	5	86	22	44	26
Elymus trachycaulus F	7.2	40.4	12.5	0.68	0.83	0.12	0.15	1	199	69	48	29
Festuca pratensis Su	5.9	41.5	14.7	0.38	1.26	0.09	0.15	2	91	38	46	26
Melica bulbosa Su	8.4	37.7	15.4	0.25	2.18	0.06	0.20	4	50	16	51	25
Poa fendleriana Su	8.2	71.5	21.3	0.29	1.27	0.06	0.15	4	224	32	76	24
Poa fendleriana F	5.9	39.9	16.8	0.40	0.76	0.09	0.12	2	88	29	46	27
Poa pratensis Sp	11.1	18.0	33.6	0.51	1.56	0.12	0.18	5	58	26	25	17
Stipa comata Su	7.3	38.4	13.5	0.27	1.29	0.06	0.16	5	335	31	100	22
Stipa lettermanii Sp	12.2	31.7	14.0	0.54	1.61	0.09	0.05	2	66	22	14	20
Stipa lettermanii Su	7.6	38.9	11.6	0.21	1.05	0.05	0.18	4	104	11	49	23
Stipa lettermanii F	4.2	41.9	12.4	0.60	0.41	0.09	0.10	1	81	27	52	18
Stipa nelsoni Sp	17.5	28.2	17.5	0.54	2.28	0.14	0.28	2	62	42	24	29
Stipa nelsoni Su	6.6	37.2	9.8	0.50	1.00	0.12	0.08	4	132	43	52	28
Stipa nelsoni F[e]	5.0	43.7	10.5	0.59	1.15	0.08	0.18	1	123	24	48	26
Sedges												
Carex aquatilus Su	12.8	32.1	17.8	0.51	1.46	0.22	0.19	9	184	107	74	33
Carex douglasii F	5.1	30.8	17.3	0.65	1.08	0.08	0.11	3	201	48	56	29
Carex egglestoni Su	6.4	30.6	18.3	0.80	2.24	0.09	0.16	3	75	75	53	25
Carex hoodii Sp	14.7	27.5	20.7	0.34	1.52	0.12	0.15	1	66	20	36	28
Carex hoodii Su	8.2	35.8	15.7	0.54	2.13	0.09	0.12	2	39	39	44	22
Carex hoodii F[e]	6.1	34.4	15.3	0.82	1.41	0.11	0.09	1	177	39	58	22
Carex petasata Su	7.8	38.8	18.7	0.41	0.85	0.09	0.12	3	83	29	41	31
Carex vallicola F	9.0	36.5	12.4	0.56	0.90	0.16	0.12	2	521	109	86	44
Browse												
Amelanchier alnifolia Su	8.9	40.3	18.2	1.43	0.25	0.26	0.13	3	46	12	38	32
Chrysothamnus viscidiflorus Su	9.5	39.8	14.9	1.03	2.05	0.17	0.21	12	75	40	91	51
Chrysothamnus viscidiflorus F	12.0	29.3	14.5	1.23	1.96	0.23	0.06	12	82	22	18	41
Populus tremuloides Su	6.1	33.3	27.9	1.27	0.57	0.21	0.03	3	17	20	13	44
Populus tremuloides F	6.2	40.6	21.2	0.73	0.96	0.16	0.21	10	44	22	9	75
Ribes cereum Su	5.1	52.2	18.4	0.94	0.88	0.19	0.17	7	105	26	55	46
Ribes cereum F	4.9	58.6	15.5	0.75	0.46	0.16	0.09	4	40	18	111	41
Ribes montigenum Sp[e]	20.1											
Salix wolfii Su	8.5	30.9	25.2	1.21	0.42	0.29	0.16	4	105	46	46	66
Sambucus racemosa F	9.3	51.8	14.4	1.18	1.09	0.22	0.16	4	40	108	37	20
Symphoricarpos oreophilus Sp[e]	12.4											
Symphoricarpos oreophilus Su	6.6	49.0	12.4	0.77	1.37	0.19	0.16	7	308	196	33	32
Symphoricarpos oreophilus F	5.9	38.5	17.3	1.14	1.25	0.22	0.20	5	69	150	15	25

[a] Crude protein is the percent of nitrogen in each sample x 6.25, because most proteins contain about 16 percent nitrogen.

[b] Acid Detergent Fiber reflects the amounts of carbohydrates not solubilized by acid detergent, these undigestible carbohydrates are cellulose, lignin, lignified nitrogen (undigestible), cutin, silica, and some pectins (Church and Pond 1988).

[c] Total nonstructural carbohydrates are the percent of sugars in a sample.

[d] The relative percent of each of these species in elk and sheep diets (if any) can be found in appendix A, table A4.

[e] These species composed less than 90 percent of seasonal diets, but were subjected to nutritional analyses.

Table B2—Percent water content by season of forbs, grasses, sedges, rushes, and browse in 1993 and 1994 elk and domestic sheep feeding sites. Browse values are for 1994 only.

	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
Species	Spring	Summer	Fall	Summer	Fall	Spring	Summer	Fall	Summer	Fall
						Percent				
Forbs										
Achillea millefolium	82.4	75.9	64.8	72.8	67.8	78.6	70.8	47.5	65.9	52.9
Agastache urticifolia	84.9			75.0	46.4	86.9	71.0			
Agoseris glauca				76.9		84.2				
Androsace septentrionalis		40.0			70.0	73.5			50.0	
Antennaria microphylla									52.4	
Antennaria parvifolia				61.5	58.8				49.2	
Arabis drummondii		70.7		47.1		73.4	60.2	15.4	50.5	23.3
Artemisia cana[a]		68.8		60.0		81.8			81.8	
Artemisia dracunculus						80.3				
Artemisia ludoviciana		69.2					70.2			
Artemisia michauxiana		70.8				76.1	59.5	54.6	67.8	44.7
Artemisia tridentata[a]				52.4	57.5				40.0	37.9
Aster chilensis				64.5		86.7				
Aster foliaceous	82.7	71.4							63.8	
Astragalus agrestis									55.3	16.7
Astragalus convallarius				56.7					28.6	
Calochortus nuttallii		81.3				84.8				
Chenopodium capitatum						67.7				
Chenopodium fremontii		73.3		68.4	19.3	84.7	73.2		63.3	
Chrysothamnus viscidiflorus[a]		81.2		40.0		75.0			35.3	
Clematis hirsutissima				66.7		75.0			39.4	
Collomia debilis							100.0			
Collomia linearis					41.7				73.2	
Crepis acuminata				62.1						
Delphinium nuttallianum				79.2		87.7				
Delphinium occidentale		79.2		50.0		85.4				
Descurainia californica	100.0	64.1	58.1	76.9		75.3	34.2		62.1	
Draba crassifolia				50.0						
Erigeron eatonii		81.3			38.3					
Erigeron elatior		84.0								
Erigeron speciosus							75.1		34.4	
Erigeron ursinus		82.4		66.7	55.0	80.9		0.0	68.2	
Euphorbia brachycera							59.3			
Fragaria vesca	66.7	71.2		68.1	56.2	71.9	61.3	0.0	60.2	51.8
Fritillaria atropurpurea		40.0				93.9				
Galium aparine		71.0								
Galium bifolium				62.5					68.2	
Galium boreale				75.6			56.7			
Gentianella amarella							23.1		74.4	
Geranium viscosissimum	85.0	85.1		76.5		76.8	66.7	43.8	63.3	
Hackelia floribunda		85.0		85.0	92.3	95.3			66.7	
Heracleum lanatum							70.0			
Hydrophyllum capitatum							90.9		87.5	
Lathyrus lanzwertii		81.7		70.5	51.3	81.2	64.2		70.6	30.0
Lepidium densiflorum						84.9	78.7		62.5	
Lesquerella alpina						75.8				
Linum perenne		80.0				85.7				
Lomatium graveolens						78.1				
Lupinus lepidus		80.0			71.4	68.6				
Lupinus sericeus	78.7	71.4		75.3		78.0	39.0		70.3	
Mertensia arizonica	87.8	87.5		79.7	61.6	85.9	81.6	20.8	70.4	
Mertensia brevistyla						79.9				
Monolepis nuttalliana				65.0						
Nemophila breviflora						87.4			68.4	

(con.)

Table B2 (Con.)

Species	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
	Spring	Summer	Fall	Summer	Fall	Spring	Summer	Fall	Summer	Fall
						Percent				
Orthocarpus tolmei		63.6		70.7		77.8				
Osmorhiza chilensis		83.6	74.4	75.0			79.5	54.2	66.1	
Penstemon cyananthus						79.9				
Penstemon humilis				40.0						
Penstemon rydbergii				72.6	52.1				56.3	33.3
Phacelia hastata						100.0				
Phlox longifolia				56.3	50.0	75.0			40.2	14.3
Polemonium caeruleum									86.7	
Polygonum aviculare		50.0		63.6					37.1	
Polygonum douglasii		63.6		65.9		74.9	63.7	41.8	52.5	47.6
Populus tremuloides[a]		73.9								
Potentilla anserina	72.0	73.0		65.9	56.8	73.8			59.5	36.8
Ranunculus inameos		68.4		66.1	67.5	80.5	30.0		60.2	
Rudbeckia occidentalis					66.7					
Rumex salicifolius				42.9					77.1	
Senecio multilobatus						79.4	80.0			
Senecio serra	87.7	79.6		62.9	18.2	86.2	80.7		79.8	
Silene antirrhina										0.0
Smilacina stellata	80.0	73.2				81.0	72.2			
Solidago sparsiflora				63.5						
Stellaria jamesiana	73.3[b]	77.7		64.6	22.2	80.0	76.9		56.3	
Swertia radiata									77.9	
Symphoricarpos oreophilus[a]		80.0		33.3						
Taraxacum officinale				55.6		81.2	40.0		54.5	40.0
Thalictrum fendleriana		78.9	40.0	60.1	52.9		75.0			
Tragopogon dubius						70.0	80.0			
Unknown forb	100.0									
Urtica dioica						85.1	76.5			
Valeriana acutiloba				40.0						
Valeriana occidentalis					40.0	84.7				
Vicia americana	78.2	75.1		68.3	61.1	77.5	60.0	0.0	58.6	0.0
Viola nephrophylla									66.7	
Viola nuttallii	86.7	75.5		76.7	88.2	82.8	75.6	50.0	70.5	
Viola purpurea						76.2				
Grasses										
Agrostis exarata									59.1	
Bromus anomalus				61.2		67.6			51.8	0.0
Bromus carinatus	76.2[b]	76.7	35.2	63.6	51.4	77.3	60.7	42.5	60.7	37.7
Bromus inermis		73.1		70.8	44.9	76.0			52.0	
Dactylis glomerata							71.9		37.9	
Deschampsia caespitosa									55.1	
Elymus elymoides									18.2	
Elymus spicatus		75.0				66.0			37.7	
Elymus trachycaulus	68.9	65.2	40.6	61.5	49.9	71.0	55.6	45.1	54.3	30.1
Festuca ovina							59.5			
Festuca pratensis				63.0					52.7	
Hordeum brachyantherum									60.4	
Melica bulbosa	66.0	64.6	22.6	54.4	29.2	67.4	57.0		16.4	
Poa fendleriana				50.6	56.7	67.6	41.2		46.1	35.5
Poa nervosa									45.1	9.1
Poa pratensis	62.4	70.2	54.4	64.5	55.4	69.1	60.4	43.6	58.2	39.2
Poa secunda						70.7			57.1	
Stipa comata									50.9	
Stipa lettermanii	64.1	60.0		55.6	36.5	58.4	55.6	29.4	45.0	21.1
Stipa nelsonii	62.0	62.8		58.4	46.1	64.6	54.4	17.0	48.3	21.7

(con.)

Table B2 (Con.)

Species	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
	Spring	Summer	Fall	Summer	Fall	Spring	Summer	Fall	Summer	Fall
	Percent									
Sedges and rushes										
Carex aquatilis									62.9	
Carex douglasii						65.6				37.7
Carex egglestonii									61.5	
Carex hoodii	71.6	72.8	33.6	63.5	48.5	66.8	54.7		56.7	34.8
Carex microptera				59.5						
Carex occidentalis		62.9								
Carex petasata				44.4					38.0	
Carex sp.				58.1						
Carex stenophylla						55.6			44.2	
Carex vallicola				59.2		61.9			48.6	18.4
Juncus arcticus				0.0		62.4			64.4	
Browse										
Amelanchier alnifolia									32.9	
Artemisia tridentata										26.7
Chrysothamnus nauseosus						100.0				
Chrysothamnus viscidiflorus								37.1	39.4	17.0
Eriogonum umbellatum									81.8	
Populus tremuloides							48.4		59.8	41.2
Ribes cereum									46.9	24.1
Ribes montigenum						85.7			60.8	
Salix wolfii							55.3			
Sambucus racemosa							76.2		60.4	62.2
Symphoricarpos oreophilus						93.7	63.1	37.8	48.9	32.7

[a] Woody plants with a basal stem diameter ≤0.32 cm were considered to be forbs due to their small size and forb-like texture.

[b] Percents where one sample was not available for calculation.

Table B3—Poisonous properties of browse (b), forb (f), grass (g), rush (r), and sedge (s) species grouped by family, their affect[a] on cattle and/or domestic sheep, their origin (N = native, I = introduced), and life span (A = annual, B = biennial, P = perennial).

Taxon by family and form		Poisonous principles				Origin		Life span		
		Toxin(s)	Cattle	Sheep	Poisoning methods and notes	N	I	A	B	P
Aceraceae										
Acer glabrum	b					x				x
Berberidaceae										
Mahonia repens	b	Alkaloids[b]			Not a serious problem[b]	x				x
Boraginaceae										
Cynoglossum officinale	f	Alkaloids[c]	x[c]				x		x	
Hackelia floribunda	f					x				x
Lappula occidentalis	f					x		x		
Lithospermum ruderale	f					x				x
Mertensia arizonica	f					x				x
Mertensia brevistyla	f					x				x
Caprifoliaceae										
Sambucus caerulea	b	Alkaloids[d], cyanic acid[d]	x[d]			x				x
Sambucus racemosa	b	Alkaloids[d]; nitrates[e]; cyanic acid[g]	x[d]		Concentrated in root[f]	x				x
Symphoricarpos oreophilus	b					x				x
Caryophyllaceae										
Silene antirrhina	f					x		x		
Stellaria jamesiana	f					x				x
Stellaria longifolia	f					x				x
Stellaria media	f	Nitrates[g]			Toxic amounts recorded[g]		x	x	x	
Celastraceae										
Pachystima myrsinite	b					x				x
Chenopodiaceae										
Chenopodium capitatum	f				Potential nitrates[d]	x				x
Chenopodium fremontii	f	Potential nitrates[d]			Potential nitrates[d]	x		x		
Monolepis nuttalliana	f	Nitrates[b]	x[b]	x[b]		x		x		
Compositae										
Achillea millefolium	f	Alkaloids[g], glycosides[g]			Affects livestock[f]	x				x
Agoseris glauca	f					x				x
Antennaria luzuloides	f					x				x
Antennaria microphylla	f					x				x
Antennaria parvifolia	f					x				x
Artemisia cana	b					x				x
Artemisia dracunculus	f					x				x
Artemisia frigida	b					x				x
Artemisia ludoviciana	f					x				x
Artemisia michauxiana	f					x				x
Artemisia tridentata	b	Phytotoxins[e]		x[h]		x				x
Aster chilensis	f	Secondary selenium accumulator[f]			May affect livestock[f]	x				x
Aster foliaceous	f				Secondary selenium accumulator?[b]	x				x
Balsamorhiza sagittata	f					x				x
Carduus nutans	f				Toxic levels of nitrates found in *C.* spp.[g]		x	x	x	
Chaenactis douglasii	f					x			x	x
Chrysothamnus nauseosus	b	Unknown[c]			May affect livestock[c]	x				x
Chrysothamnus viscidiflorus	b					x				x
Crepis acuminata	f					x				x
Erigeron eatonii	f					x				x
Erigeron elatior	f					x				x
Erigeron speciosus	f					x				x
Erigeron ursinus	f					x				x
Machaeranthera canescens	f				*M.* spp. in Wyoming are generally unpalatable[f]	x			x	x
Rudbeckia occidentalis	f	Unknown[g]		x[f]		x				x
Senecio integerrimus	f	Alkaloids[f]			Affects livestock[f]	x				x
Senecio multilobatus	f				Suspect alkaloids in *S.* spp.[b]	x				x

(con.)

Table B3 (Con.)

Taxon by family and form		Poisonous principles: Toxin(s)	Cattle	Sheep	Poisoning methods and notes	Origin: N	I	Life span: A	B	P
Senecio serra	f				Suspect alkaloids in *S.* spp.[b]	x				x
Solidago sparsiflora	f				Potential high levels of nitrates and resinoids[d]	x				x
Taraxacum officinale	f						x			x
Tetradymia canescens	b	Photosensitizer[g]		x[g]	Can cause liver damage in sheep[g]; most toxic May-July[b]	x				x
Tragopogon dubius	f						x		x	
Viguiera multiflora	f					x				x
Cruciferae										
Arabis drummondii	f					x			x	x
Descurainia californica	f					x		x	x	
Descurainia sophia	f						x	x		
Draba crassifolia	f					x			x	x
Erysimum asperum	f					x			x	x
Lepidium densiflorum	f					x		x		
Lesquerella alpina	f					x				x
Schoencrambe linifolia	f					x				x
Thelypodiopsis sagittata	f					x			x	x
Thlaspi arvense	f	Cyanogenetic glycosides[f]			Affects livestock[f]		x	x		
Cupressaceae										
Juniperus communis	b	Phytotoxins[e]			Potential livestock abortient[h]	x				x
Juniperus scopulorum	b	Phytotoxins[e]			Potential livestock abortient[h]	x				x
Cyperaceae										
Carex aquatilis	s					x				x
Carex douglasii	s					x				x
Carex egglestonii	s					x				x
Carex hoodii	s					x				x
Carex microptera	s					x				x
Carex occidentalis	s					x				x
Carex petasata	s					x				x
Carex stenophylla	s					x				x
Carex vallicola	s					x				x
Euphorbiaceae										
Euphorbia brachycera	f				May affect sheep and cattle[b]	x				x
Fumariaceae										
Corydalis aurea	f	Alkaloids[f]	x[f]	x[f]		x		x	x	x
Gentianaceae										
Gentianella amarella	f					x				x
Swertia radiata	f					x				x
Geraniaceae										
Geranium viscosissimum	f					x				x
Gramineae										
Agropyron cristatum	g				Ergot poisoning in *A.* spp.[g]		x			x
Agrostis exarata	g				Ergot poisoning in *A.* spp.[g]	x				x
Bromus anomalus	g					x				x
Bromus carinatus	g					x				x
Bromus inermis	g	Ergot poisoning[g]					x			x
Bromus tectorum	g	Mechanical injury[f]	x[f]		Suspect for ergot poisoning[f]		x	x		
Catabrosa aquatica	g	Severe acid poisoning[i]	x[i]		Can cause poisoning when consumed in large quantities[i]					
Dactylis glomerata	g					x				x
Deschampsia caespitosa	g					x				x
Elymus cinereus	g				Ergot poisoning in *E.* spp.[g]	x				x
Elymus elymoides	g	Mechanical injury[j]			Ergot poisoning in *E.* spp.[g]	x				x
Elymus hispidus	g				Ergot poisoning in *E.* spp.[g]		x			x
Elymus smithii	g	Secondary selenium absorber[k]			Ergot poisoning in *E.* spp.[g]	x				x
Elymus spicatus	g				Ergot poisoning in *E.* spp.[g]	x				x

(con.)

Table B3 (Con.)

Taxon by family and form		Poisonous principles				Origin		Life span		
		Toxin(s)	Cattle	Sheep	Poisoning methods and notes	N	I	A	B	P
Elymus trachycaulus	g				Ergot poisoning in *E.* spp.[g]	x				x
Festuca ovina	g					x				x
Festuca pratensis	g						x			x
Hordeum brachyantherum	g					x				x
Melica bulbosa	g					x				x
Phleum pratense	g						x			x
Poa fendleriana	g				Ergot poisoning in *P.* spp.[g]	x				x
Poa nervosa	g				Ergot poisoning in *P.* spp.[g]	x				x
Poa pratensis	g				Ergot poisoning in *P.* spp.[g]	x				x
Poa secunda	g				Ergot poisoning in *P.* spp.[g]	x				x
Stipa comata	g	Mechanical injury[f]			Affects livestock[f]; suspect secondary selenium absorber[k]	x				x
Stipa hymenoides	g				Suspect secondary selenium absorber[k]	x				x
Stipa lettermanii	g				Suspect secondary selenium absorber[k]	x				x
Stipa nelsonii	g				Suspect secondary selenium absorber[k]	x				x
Trisetum spicatum	g					x				x
Hydrophyllaceae										
Hydrophyllum capitatum	f					x				x
Nemophila breviflora	f					x		x		
Phacelia hastata	f					x				x
Phacelia sericea	f					x				x
Juncaceae										
Juncus arcticus	r					x				x
Labiatae										
Agastache urticifolia	f					x				x
Dracocephalum parviflorum	f					x		x	x	x
Monardella odoratissima	f					x				x
Leguminosa										
Astragalus agrestis	f	Possible alkaloids[b]			Potential selenium accumulator[b]	x				x
Astragalus argophyllus	f	Possible alkaloids[b]			Potential selenium accumulator[b]	x				x
Astragalus convallarius	f	Possible alkaloids[b]			Potential selenium accumulator[b]; locoism[f], affects livestock[f]	x				x
Astragalus tenellus	f	Possible alkaloids[b]			Potential selenium accumulator[b]	x				x
Hedysarum boreale	f					x				x
Lathyrus lanzwertii	f				Suspect abortient in *L.* spp.[h]; may cause livestock lameness[b]	x				x
Lupinus lepidus	f					x				x
Lupinus sericeus	f	Alkaloids[f]	x[f]	x[f]	Affects deer[f]; causes "crooked calf" disease[h]	x				x
Vicia americana	f					x				x
Liliaceae										
Calochortus nuttallii	f					x				x
Fritillaria atropurpurea	f				Suspect poisonous[b]	x				x
Smilacina stellata	f					x				x
Linaceae										
Linum perenne	f	Nitrates[d]			Potential saponins and cyanogenetic compounds[b]; suspect in sheep deaths[g]	x				x
Onagraceae										
Camissonia subacaulis	f					x				x
Gayophytum ramosissimum	f					x		x		
Pinaceae										
Abies lasiocarpa	b					x				x
Picea engelmannii	b					x				x

(con.)

Table B3 (Con.)

Taxon by family and form		Poisonous principles				Origin		Life span		
		Toxin(s)	Cattle	Sheep	Poisoning methods and notes	N	I	A	B	P
Pinus flexilis	b					x				x
Pseudotsuga menziesii	b	Monoterpenes and essential oils[l]				x				x
Polemoniaceae										
Collomia debilis	f					x				x
Collomia linearis	f					x		x		
Gilia aggregata	f					x			x	
Phlox longifolia	f					x				x
Polemonium caeruleum	f					x				x
Polemonium foliosissimum	f					x				x
Polygonaceae										
Eriogonum brevicaule	b					x				x
Eriogonum umbellatumb	b					x				x
Polygonum aviculare	f				*P.* spp. have potential nitrates[d], cause skin irritations and gastritis[d]; may cause nitrate poisoning and photosensitization[b]	x		x		
Polygonum douglasii	f					x		x		
Rumex salicifolius	f				Potential nitrates and oxalates[d]	x				x
Primulaceae										
Androsace septentrionalis	f					x		x		
Ranunculaceae										
Aquilegia caerulea	f					x				x
Clematis hirsutissima	f	Vesicant[g]			May poison livestock[g]	x				x
Delphinium nuttallianum	f	Alkaloids[f]	x[f]	x[f]		x				x
Delphinium occidentale	f	Alkaloids[f]	x[f]	x[f]	Occassionally poisons sheep[f]	x				x
Ranunculus inamoenus	f				Glycosides in *R.* spp.[b], forced use may poison/kill livestock[b]	x				x
Thalictrum fendleri	f					x				x
Rosaceae										
Amelanchier alnifolia	b	Cyanogens[m]		x[m]		x				x
Cercocarpus montanus	b	Cyanogenetic glycosides[d]			Affects livestock[f]	x			x	
Fragaria vesca	f					x				x
Geum macrophyllum	f					x				x
Potentilla anserina	f					x				x
Potentilla fruticosa	b					x				x
Potentilla glandulosa	f					x				x
Prunus virginiana	b	Cyanogenetic glycocide[d]			Glycocide *amygdalin* hydrolyzes to hydrocyanic acid[d]	x				x
Rosa woodsii	b					x				x
Rubus idaeus	b				Potential mechanical injury[d]	x				x
Rubiaceae										
Galium aparine	f					x		x		
Galium bifolium	f					x		x		
Galium boreale	f					x				x
Salicaceae										
Populus tremuloides	b					x				x
Salix wolfii	b					x				x
Salix drummondiana	b					x				x
Saxifragaceae										
Ribes cereum	b					x				x
Ribes montigenum	b					x				x

(con.)

Table B3 (Con.)

Taxon by family and form		Poisonous principles				Origin		Life span		
		Toxin(s)	Cattle	Sheep	Poisoning methods and notes	N	I	A	B	P
Scrophulariaceae										
Castilleja linariifolia	f				Potential selenium accumulator[b]	x				x
Orthocarpus tolmiei	f					x		x		
Penstemon cyananthus	f				Potential selenium accumulator[b]	x				x
Penstemon humilis	f				Potential selenium accumulator[b]	x				x
Penstemon rydbergii	f				Potential selenium accumulator[b]	x				x
Scrophularia lanceolata	f					x				x
Verbascum thapsus	f				Avoided by livestock due to wooliness[j]		x		x	
Umbelliferae										
Heracleum lanatum	f				Reported poisonous to cattle[b]	x			x	x
Lomatium graveolens	f					x			x	
Osmorhiza chilensis	f					x			x	
Urticaceae										
Urtica dioica	f	Stinging bristles[d], chemistry unknown[d]			Produces impenetrable stands[j]; causes welts on livestock skin[d]	x				x
Valerianaceae										
Valeriana acutiloba	f					x				x
Valeriana edulis	f					x				x
Valeriana occidentalis	f					x				x
Violaceae										
Viola adunca	f					x				x
Viola nephrophylla	f					x				x
Viola nuttallii	f					x				x
Viola purpurea	f					x				x

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[a] Normally, data are lacking for wild ungulates.
[b] Schmutz and others (1968).
[c] Lorenz and Dewey (1988).
[d] Stephens (1980).
[e] Duke (1977).
[f] Brotherson and others (1980).
[g] Kingsbury (1964).
[h] Mecke (1979).
[i] Tsvelev (1984, in Welsh and others 1993)
[j] Whitson and others (1987).
[k] Rosenfeld and Beath (1964).
[l] Oh and others (1967).
[m] Cheeke and Shull (1985).

Appendix C: Forage Use by Plant Community; Standing Herbaceous Biomass by Plant Community; and Density and Use of Woody Species by Plant Community

Table C1—Seasonal percent use of locations, feeding sites and dry herbaceous biomass by elk and domestic sheep by plant community, 1993 and 1994. Percent of woody biomass with herbaceous biomass used by elk and domestic sheep in plant community types included in 1994.

	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
Plant community	Spring	Summer	Fall[a]	Summer	Fall	Spring	Summer	Fall[a]	Summer	Fall
Aspen-Conifer										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
Percent use herbaceous biomass									16.4	
Percent use herbaceous biomass w/browse									16.4	
Aspen-Elderberry										
Percent locations	0.0	0.0	0.0	0.0	7.1	0.0	0.0	0.0	0.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0	0.0	0.0
Percent use herbaceous biomass					33.8					
Percent use herbaceous biomass w/browse										
Aspen-Elderberry-Grass[b]										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
Percent use herbaceous biomass					0.0	0.0	0.0	0.0	0.6	
Percent use herbaceous biomass w/browse									2.5	
Aspen-Elderberry-Snowberry[c]										
Percent locations	0.0	7.3	0.0	5.6	0.0	0.0	3.4	0.0	0.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	0.0	0.0
Percent use herbaceous biomass						0.0	0.3			
Percent use herbaceous biomass w/browse						0.0	0.7			
Aspen-Forb										
Percent locations	7.1	12.2	0.0	0.0	0.0	7.1	3.4	0.0	0.0	0.0
Percent feeding sites	0.0	11.8	0.0	0.0	0.0	10.0	9.1	0.0	0.0	0.0
Percent use herbaceous biomass		6.9				5.7	2.1			
Percent use herbaceous biomass w/browse						5.7	2.2			
Aspen-Grass										
Percent locations	0.0	7.3	0.0	5.6	0.0	7.1	13.8	0.0	0.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	5.0	9.1	0.0	0.0	0.0
Percent use herbaceous biomass						6.4	4.9			
Percent use herbaceous biomass w/browse						6.4	5.2			
Aspen-Mixed Brush[d]										
Percent locations	7.1	2.4	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent feeding sites	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent use herbaceous biomass	2.2									
Percent use herbaceous biomass w/browse										
Aspen-Snowberry										
Percent locations	21.4	7.3	12.5	11.1	7.1	14.3	13.8	66.7	8.0	0.0
Percent feeding sites	0.0	5.9	0.0	21.4	14.3	15.0	9.1	50.0	5.0	0.0
Percent use herbaceous biomass		6.9		6.7	19.2	3.8	2.1	27.4	3.2	
Percent use herbaceous biomass w/browse						3.8	1.4	7.4	2.0	

(con.)

Table C1 (Con.)

Plant community	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
	Spring	Summer	Fall[a]	Summer	Fall	Spring	Summer	Fall[a]	Summer	Fall
Chrysothamnus viscidiflorus-Forb[e]										
Percent locations	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0
Percent use herbaceous biomass						0.6				
Percent use herbaceous biomass w/browse						0.6				
Chrysothamnus viscidiflorus-Grass[f]										
Percent locations	0.0	4.9	25.0	11.1	14.3	17.9	0.0	0.0	8.0	0.0
Percent feeding sites	0.0	5.9	0.0	21.4	14.3	15.0	0.0	0.0	5.0	0.0
Percent use herbaceous biomass		1.3		9.6	11.9	3.3			11.1	
Percent use herbaceous biomass w/browse						3.3		0.0	9.3	
Chrys vis-Mixed Brush-Grass[g]										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0
Percent use herbaceous biomass									4.5	
Percent use herbaceous biomass w/browse									1.7	
Chrys vis-Snowberry-Grass[h]										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	0.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0
Percent use herbaceous biomass								18.3		
Percent use herbaceous biomass w/browse								8.9		
Elderberry-Grass										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
Percent use herbaceous biomass									12.6	
Percent use herbaceous biomass w/browse									14.1	
Forb meadow										
Percent locations	14.3	4.9	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0
Percent feeding sites	25.0	5.9	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0
Percent use herbaceous biomass	6.5	5.1				1.7				
Percent use herbaceous biomass w/browse						1.7				
Grass meadow										
Percent locations	14.3	24.4	12.5	22.2	7.1	3.6	20.7	0.0	4.0	11.1
Percent feeding sites	50.0	29.4	0.0	14.3	0.0	0.0	18.2	0.0	5.0	25.0
Percent use herbaceous biomass	5.3	4.8		12.2			4.8		2.9	9.7
Percent use herbaceous biomass w/browse							4.8		2.9	13.2
Mixed Brush										
Percent locations	0.0	2.4	12.5	0.0	0.0	7.1	3.4	0.0	20.0	22.2
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	20.0	25.0
Percent use herbaceous biomass						4.7			15.3	5.3
Percent use herbaceous biomass w/browse						4.8			3.7	2.4
Mixed Brush-Grass										
Percent locations	0.0	0.0	0.0	11.1	0.0	0.0	3.4	0.0	4.0	0.0
Percent feeding sites	0.0	0.0	0.0	14.3	0.0	0.0	0.0	0.0	5.0	0.0
Percent use herbaceous biomass				7.6					8.1	
Percent use herbaceous biomass w/browse									4.6	

(con.)

Table C1 (Con.)

Plant community	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
	Spring	Summer	Fall[a]	Summer	Fall	Spring	Summer	Fall[a]	Summer	Fall
Riparian										
Percent locations	0.0	0.0	0.0	0.0	7.1	3.6	6.9	0.0	4.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	5.0	0.0
Percent use herbaceous biomass						1.0			5.9	
Percent use herbaceous biomass w/browse						1.0			5.9	
Riparian-Sagebrush[i]										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	0.0	0.0
Percent use herbaceous biomass							4.8			
Percent use herbaceous biomass w/browse							3.0			
Sagebrush-*Chrys vis*-Grass[j]										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	0.0	0.0
Percent use herbaceous biomass							2.0			
Percent use herbaceous biomass w/browse							2.0			
Sagebrush-Conifer-Forb[k]										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
Percent use herbaceous biomass									4.8	
Percent use herbaceous biomass w/browse									4.8	
Sagebrush-Grass										
Percent locations	14.3	14.6	0.0	11.1	21.4	14.3	3.4	0.0	8.0	22.2
Percent feeding sites	0.0	11.8	0.0	7.1	28.6	20.0	0.0	0.0	10.0	0.0
Percent use herbaceous biomass		12.5		3.3	19.2	3.0			9.3	
Percent use herbaceous biomass w/browse						3.0			9.4	
Sagebrush-Mixed Brush[l]										
Percent locations	21.4	4.9	0.0	55.6	28.6	7.1	0.0	0.0	12.0	0.0
Percent feeding sites	0.0	5.9	0.0	7.1	14.3	5.0	0.0	0.0	10.0	0.0
Percent use herbaceous biomass		4.5		8.8	20.7	6.8			8.7	
Percent use herbaceous biomass w/browse						6.8			6.3	
Sagebrush-Mixed Brush-Grass[m]										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.2
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0
Percent use herbaceous biomass										18.4
Percent use herbaceous biomass w/browse										6.1
Sagebrush-Sedge										
Percent locations	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	4.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent use herbaceous biomass										
Percent use herbaceous biomass w/browse										
Sedge meadow										
Percent locations	0.0	0.0	0.0	5.6	0.0	3.6	0.0	0.0	0.0	11.1
Percent feeding sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent use herbaceous biomass										
Percent use herbaceous biomass w/browse										

(con.)

Table C1 (Con.)

	1993 Elk			1993 Sheep		1994 Elk			1994 Sheep	
Plant community	**Spring**	**Summer**	**Fall[a]**	**Summer**	**Fall**	**Spring**	**Summer**	**Fall[a]**	**Summer**	**Fall**
Snowberry										
Percent locations	0.0	0.0	0.0	5.6	7.1	0.0	0.0	0.0	0.0	0.0
Percent feeding sites	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0	0.0	0.0
Percent use herbaceous biomass					12.0					
Percent use herbaceous biomass w/browse										
Snowberry-Elderberry[n]										
Percent locations	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent feeding sites	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent use herbaceous biomass			1.2							
Percent use herbaceous biomass w/browse										
Snowberry-Forb										
Percent locations	0.0	7.3	12.5	0.0	0.0	3.6	3.4	0.0	0.0	0.0
Percent feeding sites	0.0	11.8	0.0	0.0	0.0	5.0	9.1	0.0	0.0	0.0
Percent use herbaceous biomass		2.5				5.0	6.6			
Percent use herbaceous biomass w/browse						5.0	8.7			
Snowberry-Grass										
Percent locations	0.0	2.4	0.0	11.1	0.0	3.6	6.9	0.0	4.0	11.1
Percent feeding sites	0.0	5.9	0.0	14.3	0.0	5.0	9.1	0.0	5.0	0.0
Percent use herbaceous biomass		4.5		17.7		3.9	1.0		12.1	
Percent use herbaceous biomass w/browse						3.9	2.4		10.7	
Snowberry-Mixed Brush[o]										
Percent locations	0.0	4.9	0.0	0.0	0.0	0.0	6.9	0.0	0.0	0.0
Percent feeding sites	0.0	5.9	0.0	0.0	0.0	0.0	9.1	0.0	0.0	0.0
Percent use herbaceous biomass		0.8					2.2			
Percent use herbaceous biomass w/browse							2.9			

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[a] Elk feeding sites in fall were subject to previous use by sheep.
[b] Aspen-Elderberry-Grass = Aspen-Eldby-Grass
[c] Aspen-Elderberry-Snowberry = Aspen-Eldby-Snwby
[d] Aspen-Mixed Brush = Aspen Mix Brush
[e] *Chrysothamnus viscidiflorus* = *Chrys vis*-Forb
[f] *Chrysothamnus viscidiflorus*-Grass = *Chrys vis*-Grass
[g] *Chrysothamnus viscidiflorus*-Mixed Brush-Grass = *Chrys vis*-Mixed Brush-Grass
[h] *Chrysothamnus viscidiflorus*-Snowberry-Grass = *Chrys vis*-Snowberry-Grass
[i] Riparian-Sagebrush = Riparian-Sage
[j] Sagebrush-*Chrysothamnus viscidiflorus*-Grass = Sagebrush-*Chrys vis*-Grass = Sage-*Chrys vis*-Gr
[k] Sagebrush-Conifer-Forb = Sage-Conifer-Forb
[l] Sagebrush-Mixed Brush = Sagebrush-Mix Br
[m] Sagebrush-Mixed Brush-Grass = Sage-MixBr-Grass
[n] Snowberry-Elderberry = Snowberry-Eldby
[o] Snowberry-Mixed Brush = Snowberry-Mix Br

Table C2—Mean seasonal standing dry biomass of forbs and graminoids listed by plant community according to kilograms/hectare and pounds/acre for 1993 and 1994. Spring values were calculated from elk feeding sites only. Summer and fall values were calculated from both elk and domestic sheep feeding sites.

Plant community	Spring 1993		Summer 1993		Fall 1993		Spring 1994		Summer 1994		Fall 1994	
	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac
Aspen-Conifer									1,091	972		
Forbs									71	63		
Graminoids									1,020	909		
Aspen-Elderberry					531	473						
Forbs					366	326						
Graminoids					165	147						
Aspen-Eldby-Grass									894	797		
Forbs									136	121		
Graminoids									758	676		
Aspen-Eldby-Snwby									945	842		
Forbs									191	170		
Graminoids									754	672		
Aspen-Forb			1,111	990			1,007	897	1,484	1,322		
Forbs			557	496			513	457	809	721		
Graminoids			554	494			494	440	675	602		
Aspen-Grass							692	617	1,525	1,358		
Forbs							172	153	402	358		
Graminoids							520	463	1,123	1,000		
Aspen-Mix Brush	129	115										
Forbs	58	52										
Graminoids	70	63										
Aspen-Snowberry			942	839	294	262	535	477	746	664	449	400
Forbs			563	502	220	196	309	275	278	248	85	76
Graminoids			379	337	74	66	226	202	468	417	364	324
Chrys vis-Forb							1,685	1,501				
Forbs							1,383	1,232				
Graminoids							302	269				
Chrys vis-Grass			721	643	538	479	581	518	641	571		
Forbs			213	189	24	22	111	99	15	14		
Graminoids			509	453	513	457	470	419	625	557		
Chrys vis-MixBr-Gr									993	885		
Forbs									325	290		
Graminoids									667	595		
Chrys vis-Snwby-Gr											544	485
Forbs											252	225
Graminoids											292	260
Elderberry-Grass									634	565		
Forbs									165	147		
Graminoids									469	418		
Forb meadow	369	329	1,224	1,090			423	377				
Forbs	226	201	982	875			312	278				
Graminoids	143	128	241	215			111	99				
Grass meadow	405	361	1,164	1,037					1,251	1,115	452	403
Forbs	180	160	469	418					204	182	154	137
Graminoids	225	201	695	619					1,047	933	298	266
Mixed Brush							150	134	801	714	270	241
Forbs							112	99	135	121	49	43
Graminoids							39	35	665	593	221	197
Mixed Brush-Grass			632	563					1,211	1,079		
Forbs			138	123					220	196		
Graminoids			495	441					992	884		

(con.)

Table C2 (Con.)

Plant community	Spring 1993		Summer 1993		Fall 1993		Spring 1994		Summer 1994		Fall 1994	
	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac
Riparian							2,112	1,882	1,751	1,560		
Forbs							399	356	233	208		
Graminoids							1,713	1,527	1,518	1,353		
Riparian-Sage									700	624		
Forbs									598	533		
Graminoids									102	91		
Sage-*Chrys vis*-Gr									1,356	1,209		
Forbs									371	330		
Graminoids									986	878		
Sage-Conifer-Forb									863	769		
Forbs									545	486		
Graminoids									318	283		
Sagebrush-Grass			422	376	727	647	548	488	860	767		
Forbs			50	45	125	111	209	186	241	215		
Graminoids			372	331	602	536	339	302	620	552		
Sagebrush-Mix Br			320	286	349	311	279	249	929	828		
Forbs			194	173	54	48	104	93	347	309		
Graminoids			126	112	295	263	175	156	583	519		
Sage-Mix Br-Grass											452	403
Forbs											67	59
Graminoids											386	344
Snowberry					300	267						
Forbs					104	93						
Graminoids					196	175						
Snowberry-Eldby					889	792						
Forbs					53	47						
Graminoids					836	745						
Snowberry-Forb			1,867	1,663			1,491	1,328	2,113	1,883		
Forbs			1,762	1,570			1,074	957	1,446	1,288		
Graminoids			105	94			417	372	667	594		
Snowberry-Grass			586	522			645	574	841	749		
Forbs			232	206			108	97	504	449		
Graminoids			355	316			536	478	337	300		
Snowberry-Mix Br			586	522					307	273		
Forbs			271	242					177	158		
Graminoids			314	280					130	115		

Table C3—Browse phenology, cover, mean height (m), percent use of biomass and of current annual (ann) growth by herbivores, and density. These values are listed on a seasonal basis by plant communities sampled at elk and domestic sheep feeding sites, 1994. Only browse greater than or equal to 0.32 cm in basal stem diameter and available to elk (0 to 1.83 m height) and domestic sheep (0 to 1.53 m height) were subjected to analyses in 22.6 m^2 belt transects[a].

	Phenology[a]		Percent cover[b]		Mean height (m)[b]		Percent use biomass[a]		Percent use ann growth[c]		Density[a,e]	
Plant community	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	No/ha[f]	No/ac[g]
1994 Elk-Spring												
Aspen-Forb												
Artemisia cana	1.0	0.0	1.0	0.0	0.26	0.0	0.0	0.0	0.0	0.0	0	0
Artemisia tridentata	1.0	0.0	1.0	0.0	0.32	0.0	0.0	0.0	0.0	0.0	443	179
Populus tremuloides	1.0	0.0	57.0	22.6	10.5	3.5	1.5	2.1	0.0	0.0	5,319	2,153
Ribes montigeneum	2.0	0.0	5.0	0.0	0.37	0.0	0.0	0.0	0.0	0.0	1,330	538
Sambucus racemosa	1.0	0.0	12.0	0.0	0.31	0.0	0.0	0.0	0.0	0.0	5,319	2,153
Symphoricarpos oreophilus	2.0	0.0	2.5	0.7	0.5	0.3	0.5	0.7	9.0	12.7	1,995	807
Aspen-Grass												
Populus tremuloides	2.0	0.0	8.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0	0
Sambucus racemosa	1.0	0.0	1.0	0.0	0.27	0.0	0.0	0.0	0.0	0.0	1,330	538
Symphoricarpos oreophilus	1.0	0.0	6.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	1,773	718
Aspen-Snowberry												
Artemisia tridentata	1.0	0.0	7.0	0.0	0.41	0.0	0.0	0.0	0.0	0.0	0	0
Chrysothamnus viscidiflorus	1.0	0.0	17.0	0.0	0.34	0.0	0.0	0.0	0.0	0.0	12,411	5,023
Populus tremuloides	1.0	0.0	20.3	10.3	5.3	2.1	0.0	0.0	0.0	0.0	591	239
Ribes cereum	2.0	0.0	3.0	0.0	0.53	0.0	0.0	0.0	0.0	0.0	0	0
Symphoricarpos oreophilus	1.0	0.0	46.0	16.5	0.9	0.2	0.1	0.2	0.0	0.0	10,638	4,305
Chrys *vis*-Forb												
Artemisia tridentata	1.0	0.0	5.0	0.0	0.56	0.0	0.0	0.0	0.0	0.0	1,773	718
Chrysothamnus viscidiflorus	2.0	0.0	32.0	0.0	0.36	0.0	0.0	0.0	0.0	0.0	21,720	8,790
Symphoricarpos oreophilus	2.0	0.0	1.0	0.0	0.44	0.0	1.0	0.0	2.0	0.0	443	179
Chrys *vis*-Grass												
Artemisia tridentata	1.0	0.0	7.0	5.7	0.3	0.1	0.0	0.0	0.0	0.0	3,768	1,525
Chrysothamnus nauseosus	2.0	0.0	9.0	0.0	0.44	0.0	0.0	0.0	0.0	0.0	4,876	1,973
Chrysothamnus viscidiflorus	1.7	0.6	27.0	6.6	0.3	0.1	0.0	0.0	0.0	0.0	25,709	10,404
Populus tremuloides	1.0	0.0	38.0	0.0	12.0	0.0	0.0	0.0	0.0	0.0	443	179
Ribes cereum	2.0	0.0	2.0	0.0	0.19	0.0	0.0	0.0	0.0	0.0	443	179
Symphoricarpos oreophilus	2.0	0.0	6.0	2.8	0.3	0.1	1.0	1.4	1.0	1.4	5,541	2,242
Forb meadow												
Artemisia tridentata	1.0	0.0	3.0	0.0	0.48	0.0	0.0	0.0	0.0	0.0	443	179
Mixed Brush												
Artemisia tridentata	1.0	0.0	19.0	0.0	0.37	0.0	0.0	0.0	0.0	0.0	6,206	2,511
Chrysothamnus nauseosus	1.0	0.0	4.0	0.0	0.68	0.0	1.0	0.0	4.0	0.0	443	179
Chrysothamnus viscidiflorus	1.0	0.0	14.0	0.0	0.38	0.0	11.0	0.0	0.0	0.0	4,876	1,973
Populus tremuloides	1.0	0.0	6.0	0.0	9.38	0.0	0.0	0.0	0.0	0.0	887	359
Ribes cereum	1.0	0.0	14.0	0.0	0.76	0.0	0.0	0.0	0.0	0.0	4,433	1,794
Symphoricarpos oreophilus	1.0	0.0	27.0	0.0	0.66	0.0	0.0	0.0	0.0	0.0	11,082	4,485
Sagebrush-Grass												
Artemisia cana	1.0	0.0	9.3	5.9	0.4	0.1	0.0	0.0	0.0	0.0	3,398	1,375
Artemisia tridentata	1.0	0.0	4.0	2.6	0.5	0.2	0.0	0.0	0.0	0.0	1,330	538
Chrysothamnus viscidiflorus	1.3	0.6	13.7	9.5	0.3	0.0	0.0	0.0	0.0	0.0	15,514	6,279
Symphoricarpos oreophilus	1.3	0.6	1.3	0.6	0.3	0.2	1.0	1.7	4.3	7.5	148	60
Sagebrush-Mixed Brush												
Artemisia tridentata	1.0	0.0	11.0	0.0	0.63	0.0	0.0	0.0	0.0	0.0	2,660	1,076
Chrysothamnus viscidiflorus	1.0	0.0	16.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	10,638	4,305
Populus tremuloides	1.0	0.0	11.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0	0
Ribes cereum	1.0	0.0	20.0	0.0	1.04	0.0	0.3	0.0	2.0	0.0	1,330	538
Symphoricarpos oreophilus	1.0	0.0	24.0	0.0	0.81	0.0	0.0	0.0	0.0	0.0	7,979	3,229
Snowberry-Forb												
Ribes montigeneum	2.0	0.0	1.0	0.0	0.14	0.0	18.0	0.0	9.0	0.0	1,330	538
Symphoricarpos oreophilus	2.0	0.0	19.0	0.0	0.64	0.0	0.0	0.0	0.0	0.0	7,536	3,050

(con.)

Table C3 (Con.)

Plant community	Phenology[a]		Percent cover[b]		Mean height (m)[b]		Percent use biomass[a]		Percent use ann growth[c]		Density[a,e]	
	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	No/ha[f]	No/ac[g]
Snowberry-Grass												
Artemisia tridentata	1.0	0.0	1.0	0.0	0.42	0.0	0.0	0.0	0.0	0.0	0	0
Chrysothamnus viscidiflorus	1.0	0.0	21.0	0.0	0.33	0.0	0.0	0.0	0.0	0.0	16,844	6,817
Symphoricarpos oreophilus	1.0	0.0	34.0	0.0	0.77	0.0	0.0	0.0	0.0	0.0	7,092	2,870
1994 Elk-Summer												
Aspen-Elderberry-Snowberry												
Artemisia tridentata	2.0	0.0	1.0	0.0	0.56	0.0	0.0	0.0	0.0	0.0	0	0
Populus tremuloides	1.0	0.0	23.0	0.0	7.0	0.0	4.0	0.0	0.0	0.0	6,649	2,691
Sambucus racemosa	3.0	0.0	3.0	0.0	0.26	0.0	4.0	0.0	21.0	0.0	7,979	3,229
Symphoricarpos oreophilus	3.0	0.0	10.0	0.0	0.53	0.0	2.0	0.0	0.6	0.0	6,649	2,691
Aspen-Forb												
Artemisia cana	1.0	0.0	1.0	0.0	0.26	0.0	0.0	0.0	0.0	0.0	443	179
Artemisia tridentata	1.0	0.0	1.0	0.0	0.59	0.0	0.0	0.0	0.0	0.0	0	0
Chrysothamnus viscidiflorus	2.0	0.0	1.0	0.0	0.19	0.0	0.0	0.0	0.0	0.0	0	0
Populus tremuloides	1.0	0.0	28.0	0.0	10.0	0.0	19.0	0.0	30.0	0.0	2,216	897
Aspen-Grass												
Chrysothamnus viscidiflorus	2.0	0.0	1.0	0.0	0.19	0.0	0.0	0.0	0.0	0.0	0	0
Populus tremuloides	1.0	0.0	29.0	0.0	12.0	0.0	17.0	0.0	39.0	0.0	13,741	5,561
Symphoricarpos oreophilus	2.0	0.0	1.0	0.0	0.28	0.0	4.0	0.0	0.0	0.0	443	179
Aspen-Snowberry												
Populus tremuloides	1.0	0.0	64.0	0.0	13.0	0.0	1.0	0.0	0.0	0.0	3,546	1,435
Ribes montigenum	3.0	0.0	1.0	0.0	0.22	0.0	1.0	0.0	3.0	0.0	1,773	718
Symphoricarpos oreophilus	3.0	0.0	7.0	0.0	0.44	0.0	1.0	0.0	1.0	0.0	2,660	1,076
Grass meadow												
Artemisia tridentata	2.0	0.0	1.0	0.0	0.84	0.0	0.0	0.0	0.0	0.0	443	179
Populus tremuloides	1.0	0.0	19.0	0.0	14.0	0.0	13.0	0.0	1.3	0.0	4,876	1,973
Sambucus racemosa	2.0	0.0	4.0	0.0	0.23	0.0	18.0	0.0	0.0	0.0	5,319	2,153
Symphoricarpos oreophilus	2.0	0.0	1.0	0.0	0.56	0.0	0.0	0.0	13.0	0.0	0	0
Riparian-Sagebrush												
Artemisia cana	2.0	0.0	11.0	0.0	0.36	0.0	0.0	0.0	0.0	0.0	3,103	1,256
Ribes montigenum	3.0	0.0	13.0	0.0	0.32	0.0	1.0	0.0	0.0	0.0	4,433	1,794
Salix wolfii	1.0	0.0	26.0	0.0	1.26	0.0	5.0	0.0	6.0	0.0	3,103	1,256
Symphoricarpos oreophilus	2.0	0.0	2.0	0.0	0.92	0.0	2.0	0.0	2.0	0.0	1,330	538
Sagebrush-*Chrys vis*-Grass												
Artemisia cana	3.0	0.0	9.0	0.0	0.64	0.0	0.0	0.0	0.0	0.0	2,216	897
Chrysothamnus viscidiflorus	3.0	0.0	26.0	0.0	0.28	0.0	0.0	0.0	0.0	0.0	18,617	7,534
Snowberry-Forb												
Symphoricarpos oreophilus	2.0	0.0	4.0	0.0	0.39	0.0	19.0	0.0	39.0	0.0	1,330	538
Snowberry-Grass												
Chrystothamnus viscidiflorus	2.0	0.0	1.0	0.0	0.26	0.0	0.0	0.0	0.0	0.0	443	179
Ribes montigenum	3.0	0.0	1.0	0.0	0.12	0.0	3.0	0.0	0.0	0.0	443	179
Symphoricarpos oreophilus	3.0	0.0	4.0	0.0	0.42	0.0	3.0	0.0	12.0	0.0	3,103	1,256
Snowberry-Mixed Brush												
Artemisia tridentata	3.0	0.0	3.0	0.0	0.74	0.0	0.0	0.0	0.0	0.0	1,330	538
Chrysothamnus nauseosus	3.0	0.0	6.0	0.0	0.82	0.0	1.0	0.0	0.0	0.0	5,319	2,153
Chrysothamnus viscidiflorus	3.0	0.0	8.0	0.0	0.51	0.0	0.0	0.0	0.0	0.0	3,546	1,435
Populus tremuloides	1.0	0.0	56.0	0.0	3.17	0.0	8.0	0.0	11.0	0.0	6,649	2,691
Ribes cereum	3.0	0.0	11.0	0.0	1.06	0.0	1.0	0.0	4.0	0.0	3,546	1,435
Symphoricarpos oreophilus	3.0	0.0	61.0	0.0	0.98	0.0	1.0	0.0	0.0	0.0	14,628	5,920
1994 Elk-Fall[h]												
Aspen-Snowberry												
Populus tremuloides	1.0	0.0	29.0	0.0	6.0	0.0	2.0	0.0	34.0	0.0	14,628	5,920
Ribes montigenum	4.0	0.0	10.0	0.0	0.81	0.0	0.0001	0.0	5.0	0.0	1,330	538
Sambucus racemosa	5.0	0.0	9.0	0.0	0.48	0.0	21.0	0.0	61.0	0.0	3,103	1,256
Symphoricarpos oreophilus	4.0	0.0	34.0	0.0	1.31	0.0	1.0	0.0	3.0	0.0	4,433	1,794

(con.)

Table C3 (Con.)

Plant community	Phenology[a]		Percent cover[b]		Mean height (m)[b]		Percent use biomass[a]		Percent use ann growth[c]		Density[a,e]	
	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	No/ha[f]	No/ac[g]
Sagebrush-*Chrys vis*-Grass												
Chrysothamnus viscidiflorus	4.0	0.0	41.0	0.0	0.38	0.0	5.0	0.0	8.0	0.0	29,699	12,019
Populus tremuloides	1.0	0.0	1.0	0.0	0.51	0.0	18.0	0.0	28.0	0.0	887	359
Symphoricarpos oreophilus	4.0	0.0	13.0	0.0	0.44	0.0	8.0	0.0	13.0	0.0	2,216	897
1994 Sheep-Summer												
Aspen-Conifer												
Abies lasiocarpa	1.0	0.0	3.0	0.0	64.0	0.0	0.0	0.0	0.0	0.0	887	359
Artemisia tridentata	2.0	0.0	12.0	0.0	0.59	0.0	0.0	0.0	0.0	0.0	3,989	1,615
Chrysothamnus viscidiflorus	2.0	0.0	1.0	0.0	0.2	0.0	3.0	0.0	26.0	0.0	1,330	538
Populus tremuloides	1.0	0.0	29.0	0.0	7.0	0.0	5.0	0.0	18.0	0.0	2,216	897
Symphoricarpos oreophilus	1.0	0.0	1.0	0.0	0.33	0.0	4.0	0.0	6.0	0.0	443	179
Aspen-Elderberry-Grass												
Populus tremuloides	1.0	0.0	53.0	0.0	8.0	0.0	9.0	0.0	15.0	0.0	1,773	718
Sambucus racemosa	1.0	0.0	19.0	0.0	0.83	0.0	0.0	0.0	0.0	0.0	11,525	4,664
Symphoricarpos oreophilus	2.0	0.0	1.0	0.0	0.24	0.0	23.0	0.0	17.0	0.0	887	359
Aspen-Snowberry												
Populus tremuloides	1.0	0.0	82.0	0.0	9.0	0.0	3.0	0.0	5.0	0.0	6,206	2,511
Ribes montigenum	3.0	0.0	1.0	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0	0
Sambucus racemosa	1.0	0.0	9.0	0.0	0.3	0.0	1.0	0.0	19.0	0.0	5,319	2,153
Symphoricarpos oreophilus	2.0	0.0	23.0	0.0	0.69	0.0	1.0	0.0	4.0	0.0	2,216	897
Chrys vis-Grass												
Artemisia tridentata	1.0	0.0	1.0	0.0	0.18	0.0	0.0	0.0	0.0	0.0	0	0
Chrysothamnus viscidiflorus	3.0	0.0	39.0	0.0	0.27	0.0	1.0	0.0	8.0	0.0	18,617	7,534
Erigonum umbellatum	4.0	0.0	1.0	0.0	0.06	0.0	0.0	0.0	3.0	0.0	0	0
Symphoricarpos oreophilus	3.0	0.0	1.0	0.0	0.22	0.0	8.0	0.0	21.0	0.0	887	359
Chrys vis-Mixed Brush-Grass												
Artemisia tridentata	2.0	1.4	3.5	0.7	0.4	0.3	0.0	0.0	0.0	0.0	443	179
Chrysothamnus viscidiflorus	2.5	0.7	52.5	23.3	0.3	0.1	0.5	0.7	0.0	0.0	35,904	14,530
Ribes montigenum	2.0	0.0	11.0	0.0	0.7	0.0	1.0	0.0	0.3	0.0	2,216	897
Symphoricarpos oreophilus	2.5	0.7	7.0	5.7	0.6	0.1	1.5	0.7	4.7	0.9	2,438	987
Elderberry-Grass meadow												
Abies lasciocarpa	3.0	0.0	3.0	0.0	19.0	0.0	0.0	0.0	0.0	0.0	0	0
Populus tremuloides	1.0	0.0	12.0	0.0	3.2	0.0	13.0	0.0	28.0	0.0	3,989	1,615
Ribes montigenum	4.0	0.0	11.0	0.0	0.75	0.0	0.02	0.0	3.0	0.0	887	359
Sambucus racemosa	3.0	0.0	14.0	0.0	0.48	0.0	62.0	0.0	72.0	0.0	8,865	3,588
Symphoricarpos oreophilus	3.0	0.0	1.0	0.0	1.19	0.0	0.0	0.0	13.0	0.0	0	0
Grass meadow												
Artemisia cana	1.0	0.0	1.0	0.0	0.35	0.0	0.0	0.0	0.0	0.0	443	179
Artemisia tridentata	1.0	0.0	1.0	0.0	0.38	0.0	0.0	0.0	0.0	0.0	443	179
Chrysothamnus viscidiflorus	2.0	0.0	4.0	0.0	0.3	0.0	4.0	0.0	0.0	0.0	1,330	538
Populus tremuloides	1.0	0.0	1.0	0.0	0.06	0.0	0.0	0.0	0.0	0.0	887	359
Symphoricarpos oreophilus	2.0	0.0	1.0	0.0	0.18	0.0	0.0	0.0	4.0	0.0	0	0
Mixed Brush												
Amelanchier alnifolia	1.0	0.0	3.0	0.0	0.5	0.0	1.0	0.0	18.0	0.0	3,989	1,615
Artemisia tridentata	2.0	1.4	13.5	6.4	0.6	0.2	0.0	0.0	0.0	0.0	5,541	2,242
Chrysothamnus viscidiflorus	2.0	0.0	30.3	11.2	0.4	0.0	0.7	0.6	3.0	5.2	33,245	13,454
Mahonia repens	4.0	0.0	12.0	0.0	0.13	0.0	1.0	0.0	0.0	0.0	18,174	7,355
Pachystima myrsinites	1.0	0.0	0.001	0.0	0.03	0.0	0.0	0.0	0.0	0.0	443	179
Populus tremuloides	1.0	0.0	12.0	15.6	1.2	1.6	0.5	0.7	27.0	35.4	2,438	987
Pseudotsuga menziesii	1.0	0.0	2.0	0.0	4.52	0.0	0.0	0.0	0.0	0.0	443	179
Rosa woodsii	4.0	0.0	4.0	0.0	0.25	0.0	6.0	0.0	28.0	0.0	15,957	6,458
Sambucus racemosa	1.0	0.0	14.0	0.0	0.54	0.0	1.0	0.0	0.0	0.0	11,082	4,485
Symphoricarpos oreophilus	2.3	0.6	19.7	6.4	0.8	0.2	0.8	0.3	4.7	1.2	5,762	2,332
Mixed Brush-Grass												
Chrysothamnus viscidiflorus	3.0	0.0	11.0	0.0	0.37	0.0	14.0	0.0	18.0	0.0	10,638	4,305
Symphoricarpos oreophilus	4.0	0.0	9.0	0.0	0.7	0.0	1.0	0.0	6.0	0.0	1,773	718

(con.)

Table C3 (Con.)

Plant community	Phenology[a]		Percent cover[b]		Mean height (m)[b]		Percent use biomass[a]		Percent use ann growth[c]		Density[a,e]	
	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	Mean	SD[d]	No/ha[f]	No/ac[g]
Riparian												
Artemisia cana	1.0	0.0	19.0	0.0	0.56	0.0	0.0	0.0	0.0	0.0	4,433	1,794
Sagebrush-Conifer-Forb												
Artemisia cana	1.0	0.0	11.0	0.0	0.49	0.0	0.0	0.0	0.0	0.0	2,216	897
Picea engelmannii	3.0	0.0	27.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	1,330	538
Pseudotsuga menziesii	3.0	0.0	2.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	443	179
Symphoricarpos oreophilus	2.0	0.0	1.0	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0	0
Sagebrush-Grass												
Artemisia cana	1.0	0.0	7.0	5.7	0.53	0.1	0.0	0.0	0.0	0.0	1,773	718
Artemisia tridentata	1.0	0.0	34.0	0.0	0.45	0.0	0.0	0.0	0.0	0.0	12,855	5,202
Erigonum umbellatum	2.0	0.0	6.0	0.0	0.16	0.0	32.0	0.0	40.0	0.0	3,103	1,256
Symphoricarpos oreophilus	2.0	0.0	1.0	0.0	0.40	0.0	0.0	0.0	8.0	0.0	0	0
Sagebrush-Mixed Brush												
Abies lasciocarpa	1.0	0.0	1.0	0.0	0.67	0.0	0.0	0.0	0.0	0.0	443	179
Artemisia cana	1.0	0.0	17.0	0.0	0.38	0.0	9.0	0.0	0.0	0.0	5,319	2,153
Artemisia tridentata	1.0	0.0	32.0	15.6	0.8	0.1	0.0	0.0	0.0	0.0	11,082	4,485
Chrysothamnus viscidiflorus	2.5	0.7	15.0	2.8	0.4	0.0	39.5	55.9	2.0	2.8	11,525	4,664
Pseudotsuga menziesii	1.0	0.0	1.0	0.0	0.23	0.0	0.0	0.0	0.0	0.0	443	179
Symphoricarpos oreophilus	3.0	0.0	2.0	0.0	0.7	0.0	0.0	0.0	3.0	0.0	0	0
Snowberry-Grass												
Populus tremuloides	1.0	0.0	1.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	887	359
Ribes cereum	3.0	0.0	2.0	0.0	0.56	0.0	4.0	0.0	11.0	0.0	443	179
Symphoricarpos oreophilus	2.0	0.0	42.0	0.0	0.79	0.0	1.0	0.0	1.5	0.0	14,184	5,740
1994 Sheep-Fall												
Grass meadow												
Chrysothamnus viscidiflorus	4.0	0.0	0.001	0.0	0.12	0.0	18.0	0.0	68.0	0.0	443	179
Populus tremuloides	1.0	0.0	24.0	0.0	17.0	0.0	26.0	0.0	27.0	0.0	1,330	538
Sambucus racemosa	4.0	0.0	1.0	0.0	0.67	0.0	22.0	0.0	83.0	0.0	887	359
Symphoricarpos oreophilus	1.0	0.0	0.001	0.0	0.1	0.0	1.0	0.0	0.5	0.0	443	179
Mixed Brush												
Artemisia tridentata	4.0	0.0	44.0	0.0	0.69	0.0	0.0	0.0	0.0	0.0	22,606	9,149
Chrysothamnus viscidiflorus	4.0	0.0	16.0	0.0	0.39	0.0	21.0	0.0	76.0	0.0	8,422	3,408
Erigonum umbellatum	4.0	0.0	2.0	0.0	0.22	0.0	3.0	0.0	3.5	0.0	887	359
Ribes cereum	4.0	0.0	1.0	0.0	0.42	0.0	8.0	0.0	4.0	0.0	1,773	718
Ribes montigenum	4.0	0.0	2.0	0.0	0.44	0.0	0.0	0.0	0.0	0.0	443	179
Sambucus racemosa	5.0	0.0	1.0	0.0	0.17	0.0	68.0	0.0	78.0	0.0	887	359
Symphoricarpos oreophilus	4.0	0.0	17.0	0.0	0.81	0.0	6.0	0.0	8.0	0.0	3,103	1,256
Sagebrush-Mixed Brush-Grass												
Artemisia cana	3.0	0.0	14.0	0.0	0.45	0.0	0.0	0.0	0.0	0.0	10,195	4,126
Artemisia trientata	4.0	0.0	31.0	21.2	0.6	0.2	2.0	2.8	10.5	14.8	14,406	5,830
Chrysothamnus viscidiflorus	4.0	0.0	8.5	10.6	0.3	0.0	7.5	4.9	19.0	26.9	7,092	2,870
Ribes cereum	1.0	0.0	0.3	0.0	0.1	0.0	32.0	0.0	62.0	0.0	443	179
Symphoricarpos oreophilus	4.0	0.0	6.0	7.1	0.4	0.1	5.5	7.8	10.0	2.8	1,551	628

[a] Dominant browse phenology, percent use of browse biomass, and browse density calculated from 22.6 m^2 belt transects in 100 m^2 microplots.

[b] Cover and mean height determined from all browse plants in 100 m^2 microplots.

[c] Current annual growth calculated from those individual browse plants in 100 m^2 microplots that were ocularly estimated for the percent of biomass removed by herbivory and then had an equivalent amount of biomass clipped and weighed to determine the wet weight of browse biomass utilized.

[d] Standard deviations (SD) of 0.0 indicate sample sizes of 1.

[e] Browse densities of 0 indicate that the browse species was found in the 100 m^2 microplot, but was not found in the 22.6 m^2 belt transect (where density was measured). This may indicate a low density of such browse species in the respective plant communities.

[f] No/ha = Number/hectare = Number of individuals sampled/22.56 m^2 x 10,000 m^2 /1 ha.

[g] No/ac = Number/acre = No/ha x 1 ha/2.471 ac.

[h] Browse sampled in fall 1994 elk feeding sites may have been subject to previous use by sheep.

Appendix D: Macrohabitat Use by Elk and Domestic Sheep; Use of Sheep Salt Placements by Elk, Domestic Sheep, and Mule Deer; and Use of Important Resource Points

Table D1—Measurements of macrohabitat elements associated with elk and domestic sheep locations, 1993 and 1994. These include seasonal and combined total mean distances less than or equal to 1,000 m and percents in distance intervals less than or equal to 1,000 m, of a habitat edge, horizontal elk obscurity cover (N, S, E, W, and total mean for elk and sheep), human activity, elk from mule deer and sheep, sheep from elk and mule deer, ridgetop, road, salt or natural mineral lick, sheep bed grounds and water to elk and domestic sheep locations.

					Interval (m)				
	≤1,000 m	n[a]	Mean	SD	0-100	101-200	201-403[b]	404-600	601-1,000
	Percent						*Percent*		
1993 Elk—Spring		14							
Habitat edge	100.0	14	15.4	12.5	100.0	0.0	0.0	0.0	0.0
N horizontal cover	100.0	14	76.8	81.2	71.4	21.4	7.1	0.0	0.0
S horizontal cover	100.0	14	45.8	22.3	100.0	0.0	0.0	0.0	0.0
E horizontal cover	100.0	14	51.5	39.2	92.9	7.1	0.0	0.0	0.0
W horizontal cover	100.0	14	75.9	62.9	85.7	7.1	7.1	0.0	0.0
Mean horizontal cover	100.0	14	62.5	40.2	85.7	14.3	0.0	0.0	0.0
Human activity	0.0	0							
Mule deer	0.0	0							
Ridgetop	100.0	14	108.3	94.4	64.3	21.4	14.3	0.0	0.0
Road	78.6	11	339.2	260.2	36.4	9.1	9.1	27.3	18.2
Salt or mineral lick	14.3	2	223.0	315.4	50.0	0.0	0.0	50.0	0.0
Sheep	0.0	0							
Sheep bed grounds	28.6	4	393.8	268.0	25.0	0.0	25.0	25.0	25.0
Water	100.0	14	441.3	289.0	14.3	14.3	14.3	35.7	21.4
1993 Elk—Summer		41							
Habitat edge	100.0	41	22.0	27.4	97.6	2.4	0.0	0.0	0.0
N horizontal cover	95.1	39	111.6	96.8	56.4	30.8	10.3	2.6	0.0
S horizontal cover	100.0	41	129.5	164.9	63.4	22.0	4.9	7.3	2.4
E horizontal cover	95.1	39	121.5	131.6	66.7	15.4	10.3	7.7	0.0
W horizontal cover	100.0	41	131.1	191.1	75.6	9.8	7.3	2.4	4.9
Mean horizontal cover	100.0	41	131.6	115.6	56.1	31.7	2.4	9.8	0.0
Human activity	14.6	6	605.0	416.1	33.3	0.0	0.0	0.0	66.7
Mule deer	9.8	4	82.8	73.3	75.0	25.0	0.0	0.0	0.0
Ridgetop	100.0	41	176.5	173.4	43.9	24.4	19.5	9.8	2.4
Road	90.2	37	395.0	330.2	29.7	10.8	13.5	16.2	29.7
Salt or mineral lick	29.3	12	212.3	166.8	33.3	8.3	41.7	16.7	0.0
Sheep	4.9	2	825.0	106.1	0.0	0.0	0.0	0.0	100.0
Sheep bed grounds	12.2	5	516.8	322.8	20.0	20.0	0.0	20.0	40.0
Water	78.0	32	474.9	270.7	12.5	9.4	21.9	25.0	31.3
1993 Elk—Fall		8							
Habitat edge	100.0	8	26.3	24.5	100.0	0.0	0.0	0.0	0.0
N horizontal cover	100.0	8	88.4	63.7	75.0	12.5	12.5	0.0	0.0
S horizontal cover	100.0	8	76.9	52.7	75.0	25.0	0.0	0.0	0.0
E horizontal cover	100.0	8	103.5	83.7	62.5	12.5	25.0	0.0	0.0
W horizontal cover	100.0	8	47.6	24.1	100.0	0.0	0.0	0.0	0.0
Mean horizontal cover	100.0	8	79.1	35.6	75.0	25.0	0.0	0.0	0.0
Human activity	12.5	1	780.0	0.0	0.0	0.0	0.0	0.0	100.0
Mule deer	25.0	2	160.0	141.4	50.0	0.0	50.0	0.0	0.0
Ridgetop	100.0	8	183.3	196.9	37.5	25.0	25.0	12.5	0.0
Road	100.0	8	482.3	290.7	12.5	25.0	12.5	37.5	12.5
Salt or mineral lick	87.5	7	327.6	171.5	14.3	0.0	57.1	14.3	14.3
Sheep	0.0	0							
Sheep bed grounds	37.5	3	356.7	310.9	33.3	0.0	0.0	66.7	0.0
Water	100.0	8	394.8	274.3	25.0	0.0	25.0	37.5	12.5
1993 Elk—Total		63							
Habitat edge	100.0	63	21.1	24.4	98.4	1.6			
N horizontal cover	96.8	61	100.6	89.8	62.3	26.2	9.8	1.6	
S horizontal cover	100.0	63	104.2	138.7	73.0	17.5	3.2	4.8	1.6
E horizontal cover	96.8	61	103.1	113.8	72.1	13.1	9.8	4.9	
W horizontal cover	100.0	63	108.3	159.7	81.0	7.9	6.3	1.6	3.2

(con.)

Table D1 (Con.)

	≤1,000 m	n^a	Mean	SD	Interval (m)				
					0-100	101-200	201-403^b	404-600	601-1,000
	Percent				- - - - - - - - - - - - - - - - -		*Percent*	- - - - - - - - - - - - - - - -	
Mean horizontal cover	100.0	63	109.6	100.2	65.1	27.0	1.6	6.3	
Human activity	11.1	7	630.0	385.6	28.6				71.4
Mule deer	9.5	6	93.0	95.0	66.7	16.7	16.7		
Ridgetop	100.0	63	162.2	162.8	47.6	23.8	19.0	7.9	1.6
Road	88.9	56	396.5	310.1	28.6	12.5	12.5	21.4	25.0
Salt or mineral lick	33.3	21	251.7	179.3	28.6	4.8	42.9	19.0	4.8
Sheep	3.2	2	825.0	106.1					100.0
Sheep bed grounds	19.0	12	435.8	283.5	25.0	8.3	8.3	33.3	25.0
Water	85.7	54	473.3	304.4	14.8	9.3	20.4	29.6	25.9
1994 Elk—Spring		28							
Habitat edge	100.0	28	40.1	82.1	92.9	3.6	0.0	3.6	0.0
N horizontal cover	100.0	28	88.3	74.2	64.3	28.6	7.1	0.0	0.0
S horizontal cover	100.0	28	142.4	239.6	78.6	10.7	0.0	0.0	10.7
E horizontal cover	100.0	28	107.0	162.7	71.4	17.9	3.6	3.6	3.6
W horizontal cover	100.0	28	97.6	98.4	64.3	28.6	3.6	3.6	0.0
Mean horizontal cover	100.0	28	108.8	120.3	75.0	14.3	7.1	0.0	3.6
Human activity	0.0	0							
Mule deer	7.1	2	55.0	76.4	50.0	50.0	0.0	0.0	0.0
Ridgetop	100.0	28	106.7	99.3	53.6	32.1	10.7	3.6	0.0
Road	82.1	23	457.7	326.7	8.7	21.7	17.4	17.4	34.8
Salt or mineral lick	78.6	22	416.8	299.9	13.6	22.7	13.6	13.6	36.4
Sheep	0.0	0							
Sheep bed grounds	64.3	18	579.1	293.6	11.1	0.0	16.7	22.2	50.0
Water	71.4	20	560.6	272.5	5.0	10.0	5.0	35.0	45.0
1994 Elk—Summer		29							
Habitat edge	100.0	29	28.1	33.6	93.1	6.9	0.0	0.0	0.0
N horizontal cover	100.0	29	55.6	63.5	86.2	6.9	6.9	0.0	0.0
S horizontal cover	100.0	29	73.2	98.2	79.3	13.8	3.4	3.4	0.0
E horizontal cover	100.0	29	58.2	81.0	82.8	13.8	0.0	3.4	0.0
W horizontal cover	100.0	29	74.3	129.9	82.8	10.3	3.4	0.0	3.4
Mean horizontal cover	100.0	29	65.3	72.6	82.8	10.3	6.9	0.0	0.0
Human activity	6.9	2	430.5	405.2	0.0	50.0	0.0	0.0	50.0
Mule deer	10.3	3	232.7	132.8	33.3	0.0	66.7	0.0	0.0
Ridgetop	100.0	29	103.1	102.4	55.2	31.0	10.3	3.4	0.0
Road	62.1	18	367.3	262.4	16.7	27.8	16.7	16.7	22.2
Salt or mineral lick	75.9	22	361.9	296.0	18.2	22.7	22.7	9.1	27.3
Sheep	3.4	1	621.0	0.0	0.0	0.0	0.0	0.0	100.0
Sheep bed grounds	72.4	21	387.9	306.6	14.3	23.8	14.3	28.6	19.0
Water	89.7	26	408.0	274.4	23.1	0.0	23.1	34.6	19.2
1994 Elk—Fall		3							
Habitat edge	100.0	3	69.0	50.5	66.7	33.3	0.0	0.0	0.0
N horizontal cover	100.0	3	24.3	17.6	100.0	0.0	0.0	0.0	0.0
S horizontal cover	100.0	3	20.3	11.9	100.0	0.0	0.0	0.0	0.0
E horizontal cover	100.0	3	29.3	40.5	100.0	0.0	0.0	0.0	0.0
W horizontal cover	100.0	3	19.3	9.5	100.0	0.0	0.0	0.0	0.0
Mean horizontal cover	100.0	3	23.3	19.4	100.0	0.0	0.0	0.0	0.0
Human activity	0.0	0							
Mule deer	0.0	0							
Ridgetop	100.0	3	181.7	187.3	33.3	33.3	33.3	0.0	0.0
Road	66.7	2	669.0	405.9	0.0	0.0	50.0	0.0	50.0
Salt or mineral lick	100.0	3	366.0	337.4	0.0	33.3	33.3	0.0	33.3
Sheep	0.0	0							
Sheep bed grounds	100.0	3	236.0	211.3	33.3	33.3	0.0	33.3	0.0
Water	100.0	3	520.7	327.4	33.3	0.0	0.0	0.0	66.7
1994 Elk—Total		60							
Habitat edge	100.0	60	35.8	61.7	91.7	6.7		1.7	
N horizontal cover	100.0	60	69.3	69.3	76.7	16.7		6.7	
S horizontal cover	100.0	60	102.9	179.9	80.0	11.7	1.7	1.7	5.0
E horizontal cover	100.0	60	79.5	126.5	78.3	15.0	1.7	3.3	1.7

(con.)

Table D1 (Con.)

					Interval (m)				
	≤1,000 m	n[a]	Mean	SD	0-100	101-200	201-403[b]	404-600	601-1,000
	Percent				*Percent*				
W horizontal cover	100.0	60	82.4	113.0	75.0	18.3	3.3	1.7	1.7
Mean horizontal cover	100.0	60	83.5	98.9	80.0	11.7	6.7		1.7
Human activity	3.3	2	430.5	405.2		50.0			50.0
Mule deer	8.3	5	161.6	140.5	40.0	20.0	40.0		
Ridgetop	100.0	60	108.7	104.7	53.3	31.7	11.7	3.3	
Road	71.7	43	429.7	304.2	11.6	23.3	18.6	16.3	30.2
Salt or mineral lick	78.3	47	387.9	294.6	14.9	23.4	19.2	10.6	31.9
Sheep	1.7	1	621.0	0.0					100.0
Sheep bed grounds	70.0	42	459.0	310.4	14.3	14.3	14.3	26.2	31.0
Water	81.7	49	477.1	280.5	16.3	4.1	14.3	32.7	32.7
1993 Sheep—Summer[c]		18							
Elk	0.0	0							
Habitat edge	100.0	18	23.7	41.5	88.9	11.1	0.0	0.0	0.0
Human activity	33.3	6	392.2	271.9	16.7	33.3	0.0	0.0	50.0
Mule deer	0.0	0							
Ridgetop	100.0	18	187.7	194.6	44.4	16.7	16.7	16.7	5.6
Road	100.0	18	260.9	324.2	44.4	22.2	11.1	5.6	16.7
Salt or mineral lick	38.9	7	405.0	337.2	28.6	14.3	0.0	28.6	28.6
Sheep bed grounds	33.3	6	357.5	398.9	50.0	0.0	0.0	0.0	50.0
Water	61.1	11	416.8	296.4	0.0	18.2	36.4	9.1	36.4
1993 Sheep—Fall[c]		14							
Elk	0.0	0							
Habitat edge	100.0	14	37.3	52.0	92.9	7.1	0.0	0.0	0.0
Human activity	92.9	13	213.5	238.1	46.2	15.4	15.4	15.4	7.7
Mule deer	0.0	0							
Ridgetop	100.0	14	165.0	135.6	28.6	35.7	28.6	7.1	0.0
Road	92.9	13	257.9	306.8	38.5	23.1	23.1	0.0	15.4
Salt or mineral lick	61.5	8	343.8	218.9	12.5	12.5	37.5	25.0	12.5
Sheep bed grounds	64.3	9	153.1	238.5	66.7	0.0	11.1	22.2	0.0
Water	71.4	10	220.7	241.1	30.0	30.0	30.0	0.0	10.0
1993 Sheep—Total[c]		32							
Elk		0							
Habitat edge	100.0	32	29.6	46.1	90.6	9.4			
Human activity	59.4	19	269.9	256.2	36.8	21.1	10.5	10.5	21.1
Mule deer		0							
Ridgetop	100.0	32	177.8	169.2	37.5	25.0	21.9	12.5	3.1
Road	96.9	31	259.7	311.8	41.9	22.6	16.1	3.2	16.1
Salt or mineral lick	46.9	15	372.3	271.5	20.0	13.3	20.0	26.7	20.0
Sheep bed grounds	46.9	15	234.9	316.4	60.0		6.7	13.3	20.0
Water	65.6	21	366.3	314.0	14.3	23.8	33.3	4.8	23.8
1994 Sheep—Summer		25							
Elk	4.0	1	405.0	0.0	0.0	0.0	0.0	100.0	0.0
Habitat edge	100.0	25	29.1	36.5	92.0	8.0	0.0	0.0	0.0
N horizontal cover	100.0	25	65.8	95.3	80.0	16.0	0.0	4.0	0.0
S horizontal cover	100.0	25	80.5	114.6	88.0	0.0	8.0	4.0	0.0
E horizontal cover	100.0	25	89.3	147.3	80.0	4.0	12.0	0.0	4.0
W horizontal cover	100.0	25	112.2	194.2	84.0	4.0	4.0	0.0	8.0
Mean horizontal cover	100.0	25	87.0	114.6	76.0	12.0	8.0	4.0	0.0
Human activity	52.0	13	557.8	303.0	15.4	7.7	0.0	38.5	38.5
Mule deer	4.0	1	147.0	0.0	0.0	100.0	0.0	0.0	0.0
Ridgetop	100.0	25	161.3	129.2	40.0	28.0	28.0	4.0	0.0
Road	92.0	23	330.7	264.0	26.1	8.7	26.1	21.7	17.4
Salt or mineral lick	80.0	20	480.3	287.3	10.0	10.0	20.0	25.0	35.0
Sheep bed grounds	92.0	23	416.3	274.9	13.0	8.7	30.4	26.1	21.7
Water	72.0	18	494.9	272.9	5.6	5.6	27.8	22.2	38.9
1994 Sheep—Fall		9							
Elk	0.0	0							
Habitat edge	100.0	9	65.6	73.1	77.8	11.1	11.1	0.0	0.0
N horizontal cover	100.0	9	197.2	284.7	55.6	22.2	11.1	0.0	11.1

(con.)

Table D1 (Con.)

	≤1,000 m	n[a]	Mean	SD	Interval (m)				
					0-100	101-200	201-403[b]	404-600	601-1,000
	Percent				*Percent*				
S horizontal cover	100.0	9	122.6	140.0	66.7	11.1	11.1	11.1	0.0
E horizontal cover	100.0	9	91.2	124.1	77.8	11.1	11.1	0.0	0.0
W horizontal cover	100.0	9	99.2	87.6	66.7	22.2	11.1	0.0	0.0
Mean horizontal cover	100.0	9	127.6	100.0	44.4	44.4	11.1	0.0	0.0
Human activity	66.7	6	487.7	269.5	0.0	16.7	16.7	33.3	33.3
Mule deer	0.0	0							
Ridgetop	100.0	9	132.9	112.1	44.4	33.3	22.2	0.0	0.0
Road	88.9	8	294.3	208.9	25.0	25.0	12.5	37.5	0.0
Salt or mineral lick	100.0	9	433.0	256.9	0.0	22.2	22.2	33.3	22.2
Sheep bed grounds	100.0	9	305.9	306.6	22.2	33.3	22.2	0.0	22.2
Water	88.9	8	579.0	283.7	0.0	12.5	12.5	25.0	50.0
1994 Sheep—Total		34							
Elk	2.9	1	405.0	0.0				100.0	
Habitat edge	100.0	34	38.8	50.3	88.2	8.8	2.9		
N horizontal cover	100.0	34	100.6	172.4	73.5	17.6	2.9	2.9	2.9
S horizontal cover	100.0	34	91.6	121.1	82.4	2.9	8.8	5.9	
E horizontal cover	100.0	34	89.8	139.7	79.4	5.9	11.8		2.9
W horizontal cover	100.0	34	108.8	171.2	79.4	8.8	5.9		5.9
Mean horizontal cover	100.0	34	97.7	110.9	67.6	20.6	8.8	2.9	
Human activity	55.9	19	535.7	287.2	10.5	10.5	5.3	36.8	36.8
Mule deer	2.9	1	147.0	0.0		100.0			
Ridgetop	100.0	34	153.8	123.9	41.2	29.4	26.5	2.9	
Road	91.2	31	321.3	248.1	25.8	12.9	22.6	25.8	12.9
Salt or mineral lick	85.3	29	465.6	274.5	6.9	13.8	20.7	27.6	31.0
Sheep bed grounds	94.1	32	385.3	283.6	15.6	15.6	28.1	18.8	21.9
Water	76.5	26	520.8	273.4	3.8	7.7	23.1	23.1	42.3

[a] Sample sizes differed from one ecological parameter to another. This was due to differences in sampling procedures in 1993 and 1994, missing samples, or unusable samples.

[b] 403 m = 0.25 miles.

[c] Horizontal elk obscurity cover is not available for 1993 sheep locations.

Table D2—Mean distances and percents in distance intervals of sheep salting placements used by elk, mule deer, and domestic sheep, as well as salt placement locations not used by animals from the nearest habitat edge, natural mineral lick, ridgetop, road, and water source.

Animal	Percent[a]	n[b]	Mean	SD	Interval (m)						
					n[b]	0-100	101-200	201-403[c]	404-600	601-1,000	≥1,001
						Percent					
Elk	54.4	49									
Habitat edge		39	15.8	16.6	39	100.0	0.0	0.0	0.0	0.0	0.0
Natural mineral lick		22	1,467.1	771.7	22	0.0	0.0	0.0	0.0	31.8	68.2
Ridgetop		26	49.8	101.5	22	84.6	7.7	3.8	3.8	0.0	0.0
Road		38	438.5	456.9	38	26.3	7.9	26.3	18.4	7.9	13.2
Water		47	719.4	447.0	47	18.4	0.0	6.1	12.2	30.6	32.7
Mule Deer	25.6	23									
Habitat edge		19	13.6	13.3	19	100.0	0.0	0.0	0.0	0.0	0.0
Natural mineral lick		12	1,777.8	835.0	12	0.0	0.0	0.0	0.0	33.3	66.7
Ridgetop		14	24.7	35.6	14	100.0	0.0	0.0	0.0	0.0	0.0
Road		19	453.8	485.3	19	31.6	15.8	10.5	10.5	10.5	21.1
Water		21	778.1	396.0	23	0.0	0.0	17.4	17.4	26.1	39.1
Sheep	29.0	32.2									
Habitat edge		24	41.8	44.5	24	87.5	12.5	0.0	0.0	0.0	0.0
Natural mineral lick		11	1,907.3	1,289.6	11	0.0	0.0	0.0	0.0	36.4	63.6
Ridgetop		18	69.9	104.7	18	77.8	5.6	16.7	0.0	0.0	0.0
Road		24	229.0	329.7	24	45.8	33.3	0.0	4.2	12.5	4.2
Water		26	349.8	406.5	27	44.4	7.4	11.1	0.0	29.6	7.4
No Animals	11.1	10									
Habitat edge		10	10.8	8.9	10	100.0	0.0	0.0	0.0	0.0	0.0
Natural mineral lick		0			0						
Ridgetop		5	43.2	41.3	5	100.0	0.0	0.0	0.0	0.0	0.0
Road		7	808.1	800.2	7	42.9	0.0	0.0	0.0	14.3	42.9
Water		9	512.4	357.8	9	11.1	22.2	0.0	33.3	33.3	0.0
Total	100.0	90									
Habitat edge		73	23.5	30.9	73	95.9	4.1	0.0	0.0	0.0	0.0
Natural mineral lick		35	1,692.7	1,003.8	35	0.0	0.0	0.0	0.0	31.4	68.6
Ridgetop		51	56.2	96.0	51	82.4	7.8	7.8	2.0	0.0	0.0
Road		69	411.1	48.7	69	33.3	14.5	15.9	11.6	11.6	13.0
Water		83	592.6	442.4	87	23.0	5.7	8.0	11.5	29.9	21.8

[a] These totals do not equal 90 samples. Elk sign was found exclusively at 33.3 percent, deer at 5.6 percent, and sheep at 26.7 percent of salting locations. Elk and sheep sign were found together at 3.3 percent of salting locations; elk and deer sign were found at 17.8 percent of salting locations; and, deer and sheep sign were found at 2.2 percent of salting locations.

[b] Sample sizes often differ from one ecological parameter to another due to differences in sampling procedures in 1993 and 1994, missing samples and unusable samples.

[c] 403 m = 0.25 miles.

Table D3—Mean distances and percents in distance intervals of elk dry wallows, natural mineral licks, stock ponds, sheep bed grounds, and stock watering troughs from a habitat edge, mean horizontal cover, ridgetop, road, salt or natural mineral lick, and water source.

Map 1. Willow Creek Elk and Domestic Sheep Interactions Study Area, Heber Ranger District, Uinta National Forest: 1993.

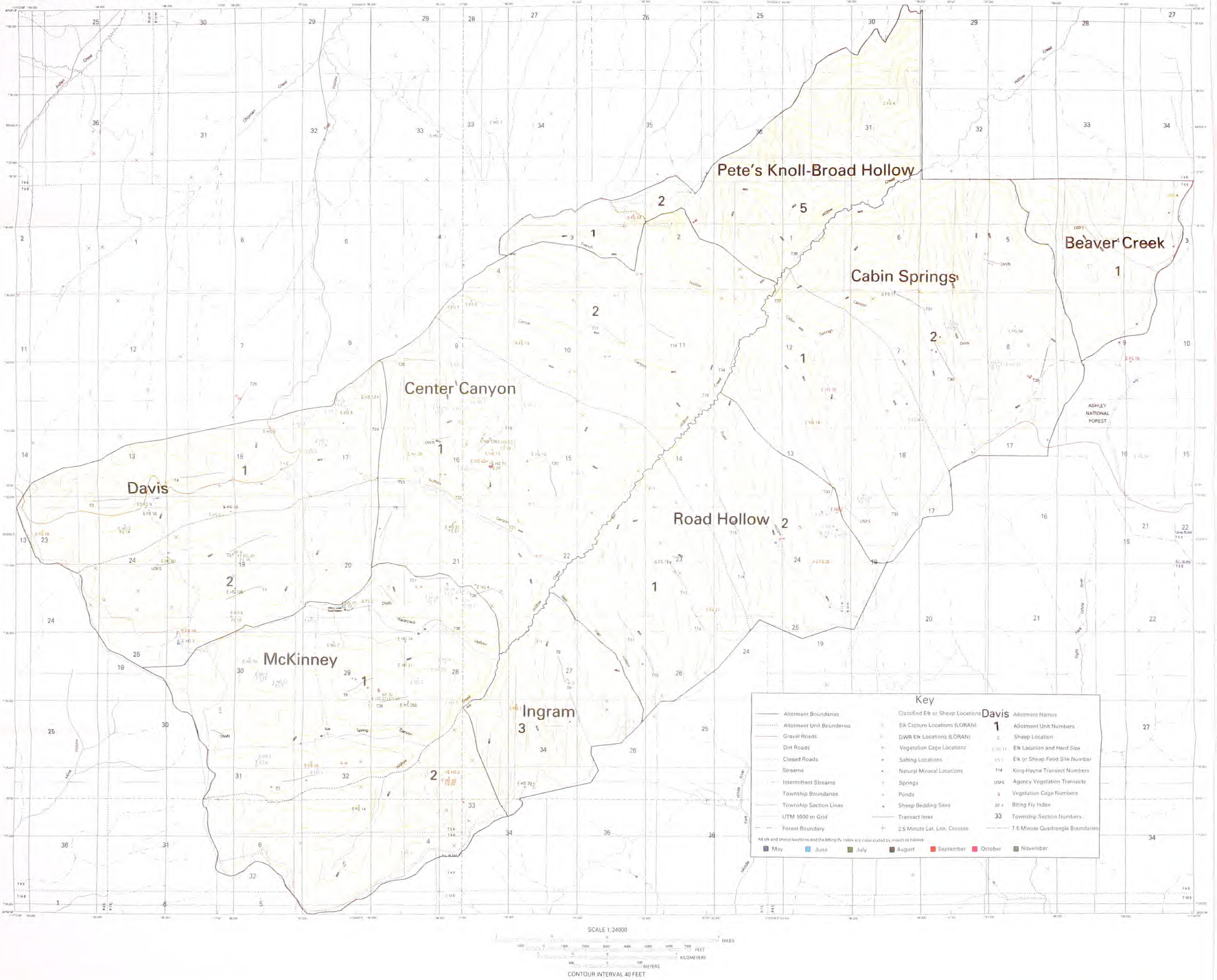

Table D3—Mean distances and percents in distance intervals of elk dry wallows, natural mineral licks, stock ponds, sheep bed grounds, and stock watering troughs from a habitat edge, mean horizontal cover, ridgetop, road, salt or natural mineral lick, and water source.

					Interval (m)					
Feature	n[a]	Mean	SD	n[a]	0-100	101-200	201-403[b]	404-600	601-1,000	≥1,001
					Percent					
Elk dry wallows										
Habitat edge	6	26.2	44.3	6	83.3	16.7	0.0	0.0	0.0	0.0
Horizontal cover (mean)	6	47.0	12.8	6	100.0	0.0	0.0	0.0	0.0	0.0
Ridgetop	6	195.0	100.7	6	0.0	50.0	50.0	0.0	0.0	0.0
Road	6	461.2	398.4	6	16.7	16.7	33.3	0.0	16.7	16.7
Salt or natural mineral lick	6	484.7	104.4	6	0.0	0.0	16.7	66.7	16.7	0.0
Water	6	487.7	243.7	6	16.7	0.0	0.0	50.0	33.3	0.0
Natural mineral licks										
Habitat edge	8	31.5	19.4	8	100.0	0.0	0.0	0.0	0.0	0.0
Horizontal cover (mean)	8	97.0	46.8	4	50.0	50.0	0.0	0.0	0.0	0.0
Ridgetop	3	103.0	89.4	4	50.0	25.0	25.0	0.0	0.0	0.0
Road	7	870.0	296.7	8	0.0	0.0	0.0	12.5	50.0	37.5
Salt or natural mineral lick	8	83.5	236.2	8	87.5	0.0	0.0	0.0	12.5	0.0
Water	8	0.0	0.0	8	100.0	0.0	0.0	0.0	0.0	0.0
Sheep bed grounds										
Habitat edge	3	15.7	4.2	3	100.0	0.0	0.0	0.0	0.0	0.0
Horizontal cover (mean)	1	62.0	0.0	1	100.0	0.0	0.0	0.0	0.0	0.0
Ridgetop	1	0.0	0.0	1	100.0	0.0	0.0	0.0	0.0	0.0
Road	3	62.7	50.1	3	100.0	0.0	0.0	0.0	0.0	0.0
Salt or natural mineral lick	3	33.7	31.7	3	100.0	0.0	0.0	0.0	0.0	0.0
Water	3	617.7	50.1	3	0.0	33.3	0.0	0.0	66.7	0.0
Stock ponds										
Habitat edge	8	29.3	28.4	8	100.0	0.0	0.0	0.0	0.0	0.0
Horizontal cover (mean)	3	53.5	19.5	3	100.0	0.0	0.0	0.0	0.0	0.0
Ridgetop	3	120.3	64.0	3	66.7	33.3	0.0	0.0	0.0	0.0
Road	9	191.9	289.4	9	66.7	0.0	11.1	0.0	22.2	0.0
Salt or natural mineral lick	9	107.3	194.8	9	77.8	11.1	0.0	0.0	11.1	0.0
Water	9	0.0	0.0	9	100.0	0.0	0.0	0.0	0.0	0.0
Water troughs										
Habitat edge	1	3.0	0.0	1	100.0	0.0	0.0	0.0	0.0	0.0
Horizontal cover (mean)	1	30.3	0.0	1	100.0	0.0	0.0	0.0	0.0	0.0
Ridgetop	1	299.0	0.0	1	0.0	0.0	100.0	0.0	0.0	0.0
Road	1	517.0	0.0	1	0.0	0.0	0.0	100.0	0.0	0.0
Salt or natural mineral lick	1	943.0	0.0	1	0.0	0.0	0.0	0.0	100.0	0.0
Water	1	0.0	0.0	1	100.0	0.0	0.0	0.0	0.0	0.0

[a] Sample sizes often differ from one ecological parameter to another due to differences in sampling procedures in 1993 and 1994, missing samples or unusable samples.
[b] 403 m = 0.25 miles.

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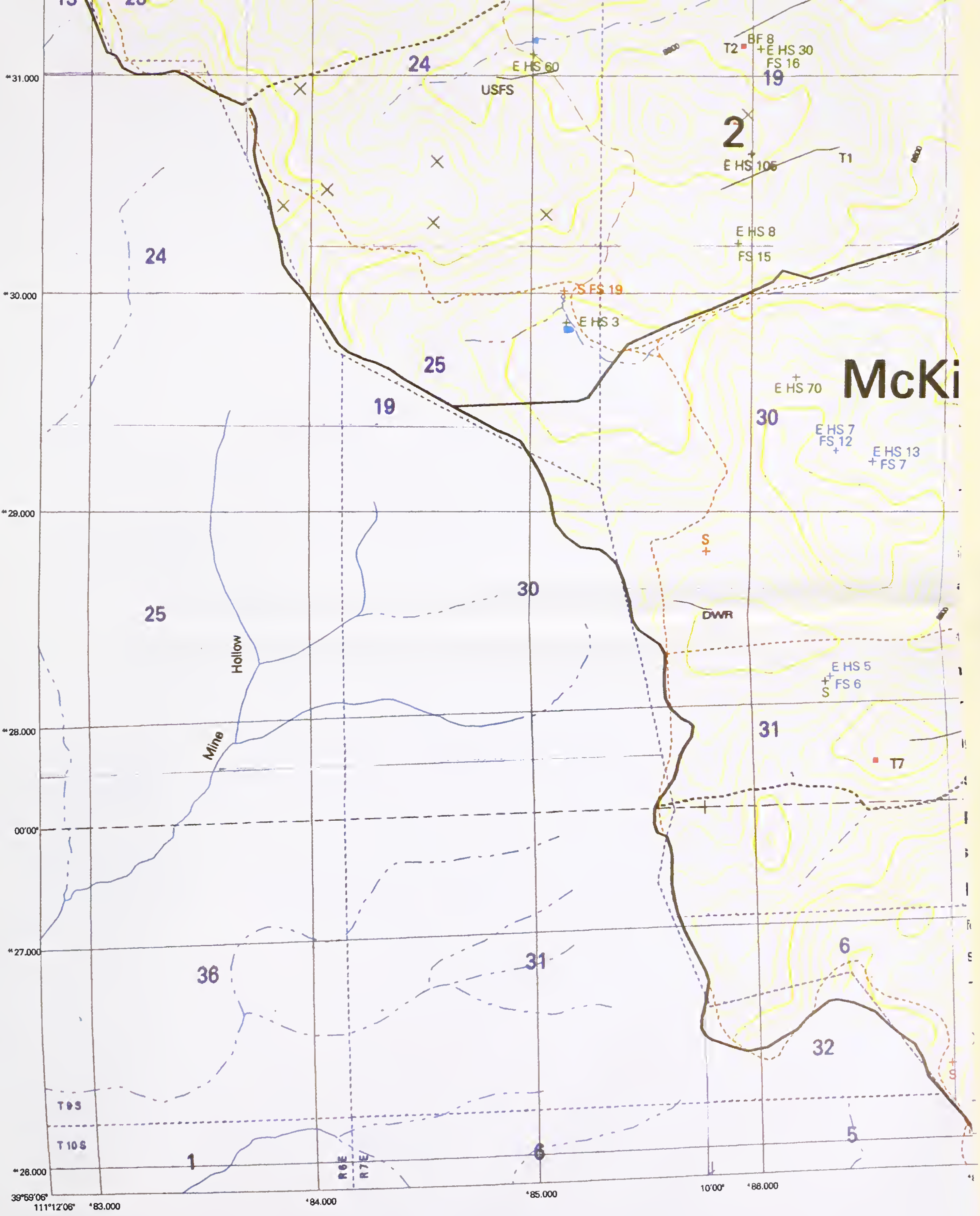
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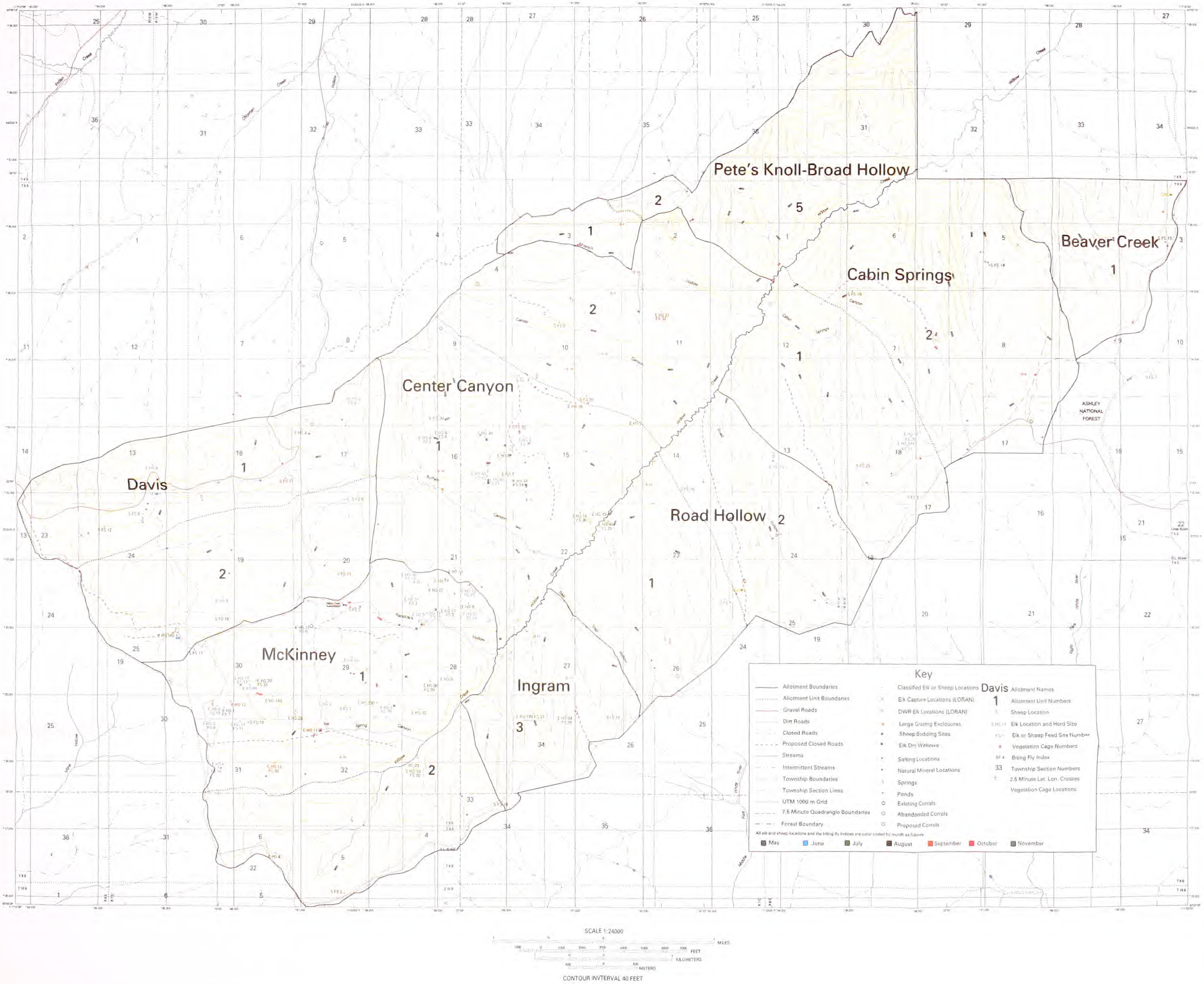
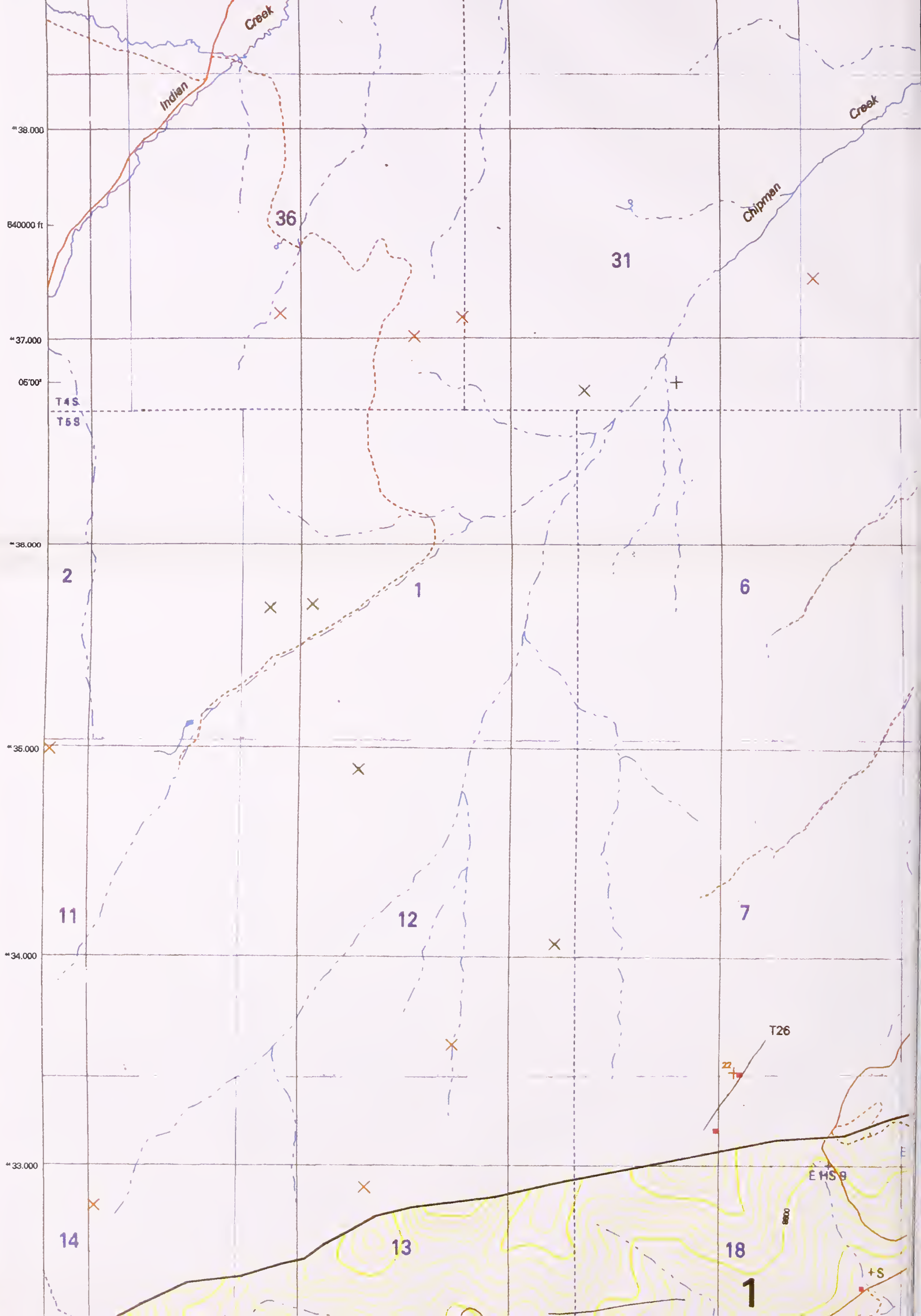
Map 2. Willow Creek Elk and Domestic Sheep Interactions Study Area, Heber Ranger District, Uinta National Forest: 1994.

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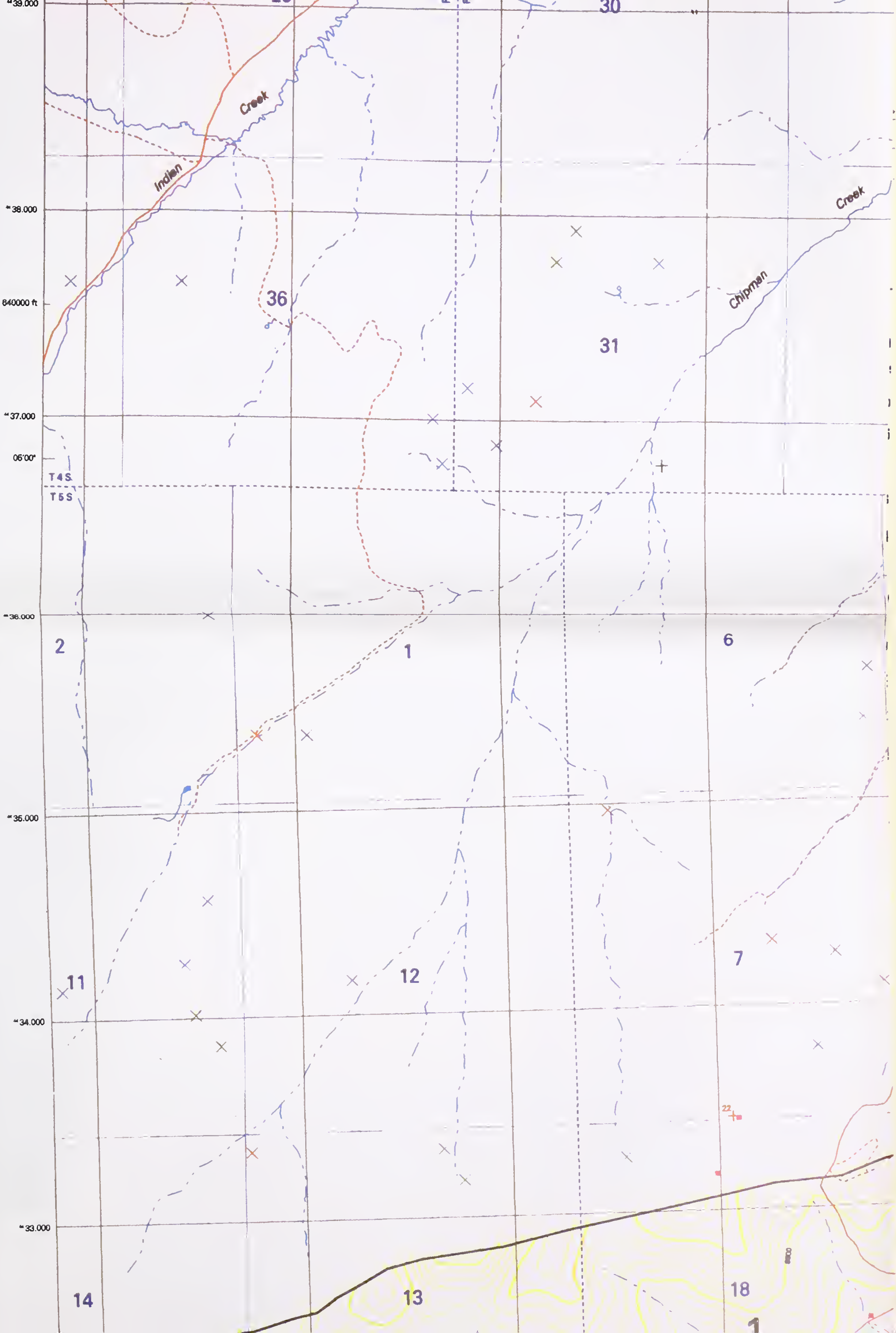
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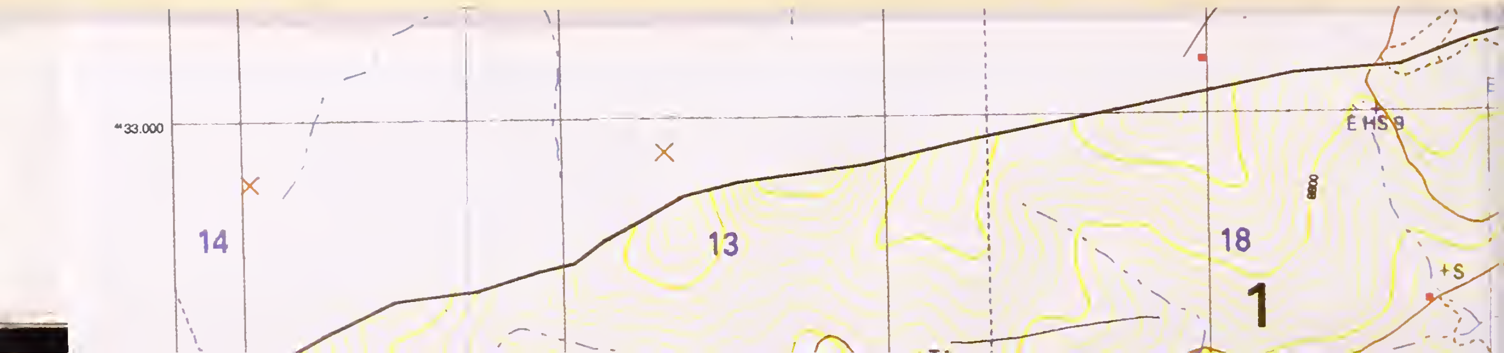

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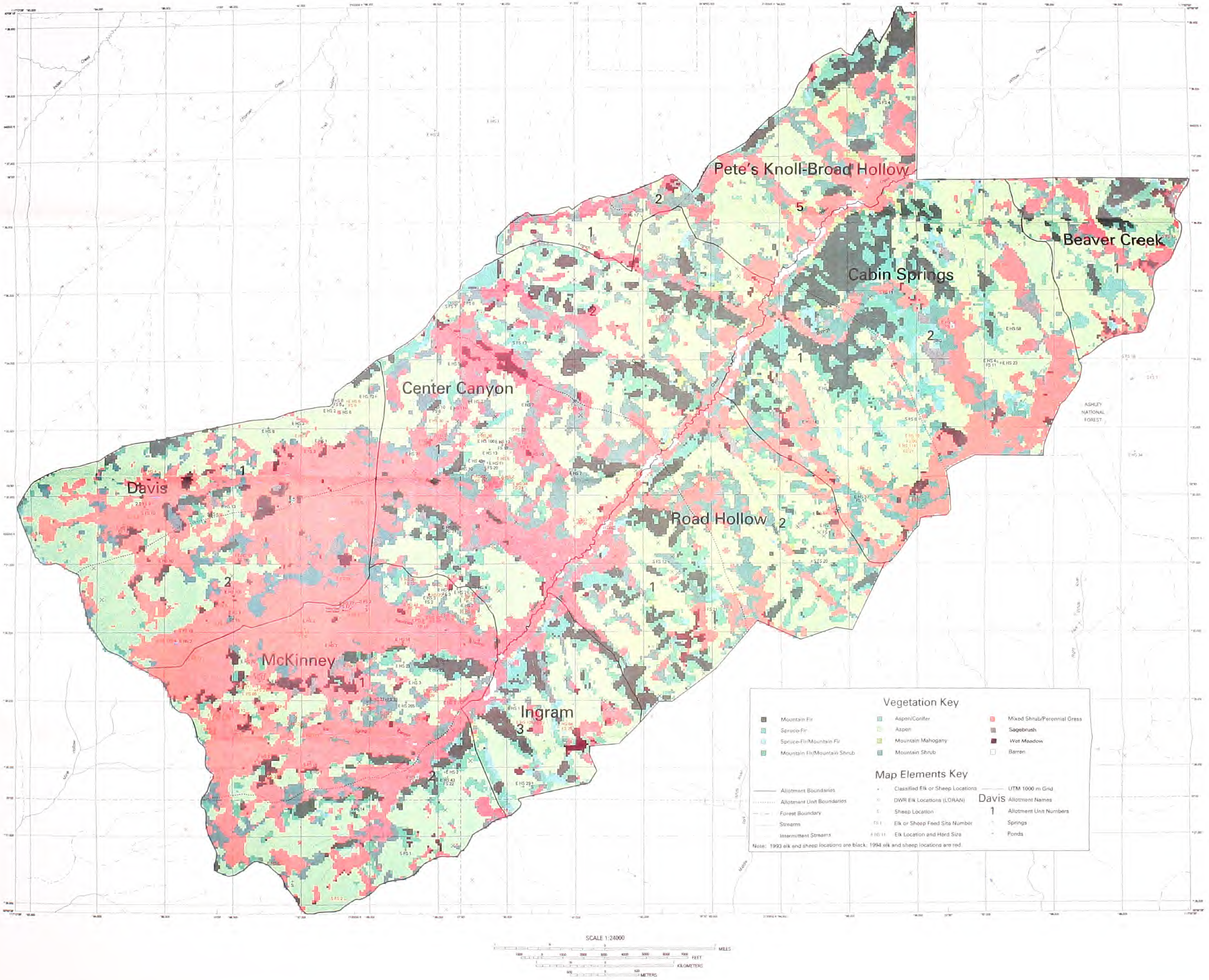
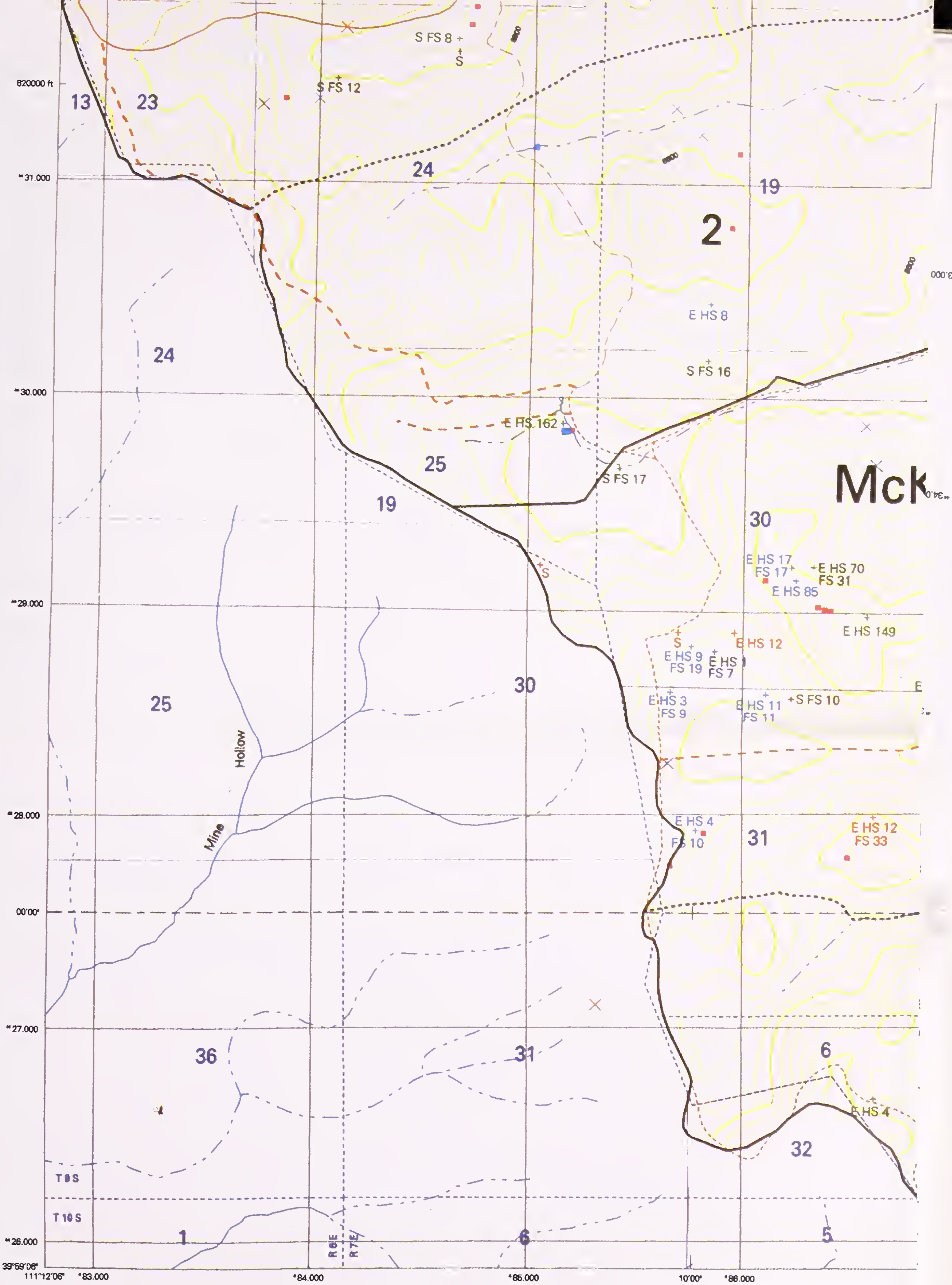
Map 3. Vegetation Cover: Willow Creek Elk and Domestic Sheep Interactions Study Area, Heber Ranger District, Uinta National Forest: 1993 and 1994.

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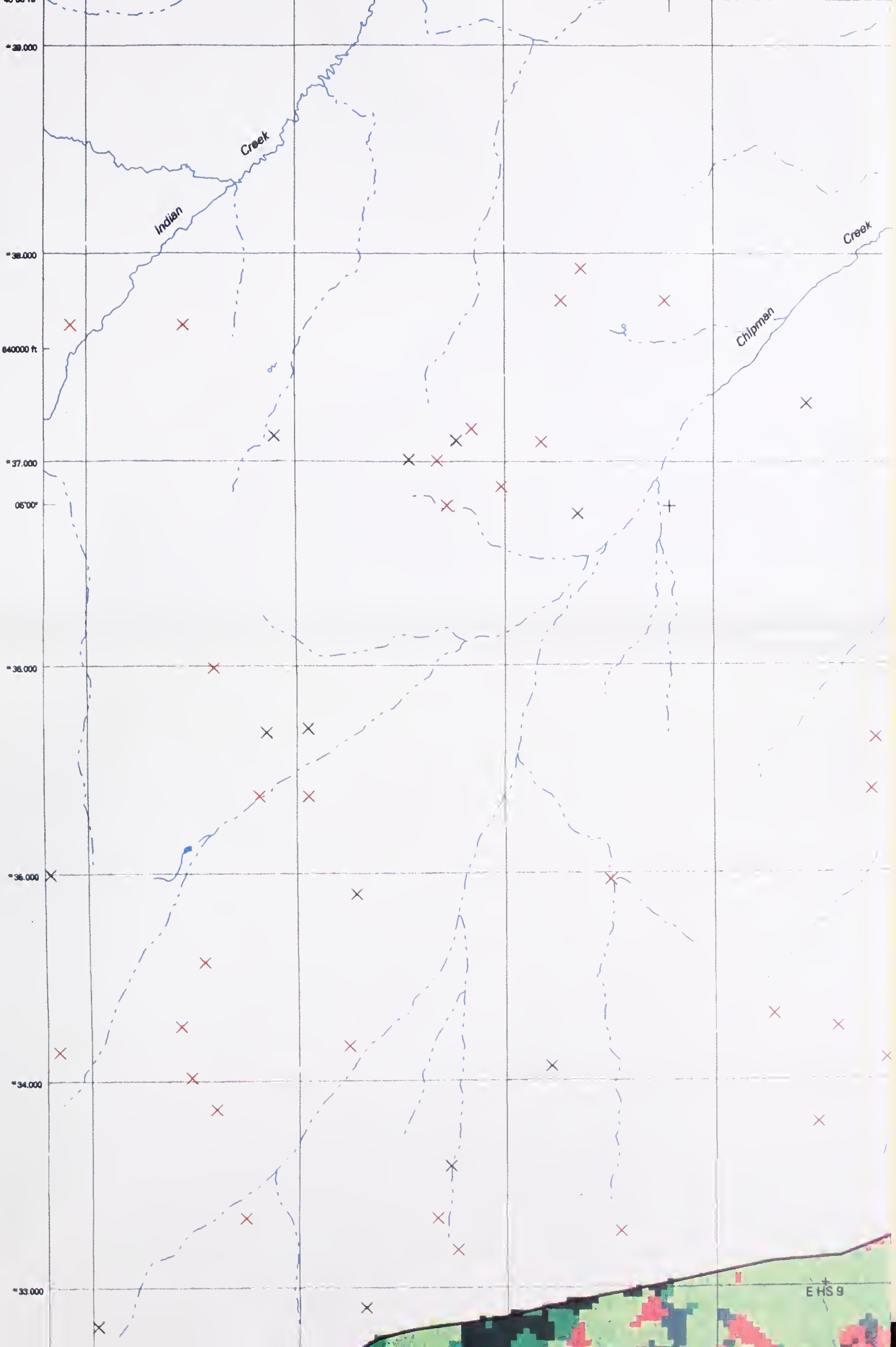
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Beck, Jeffrey L.; Flinders, Jerran T.; Nelson, Deanna R.; Clyde, Craig L.; Smith, H. Duane; Hardin, Perry J. 1996. Elk and domestic sheep interactions in a north-central Utah aspen ecosystem. Res. Pap. INT-RP-491. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 114 p.

Relationships of elk and domestic sheep sharing a common 100.1 km^2 (24,735 acre) range dominated by aspen were studied from May 1993 through October 1994 in the Willow Creek Demonstration Area on the Heber Ranger District, Uinta National Forest, in north-central Utah. Important findings included seasonal feeding site selection, preferences for forage, dietary overlap, use of natural mineral licks, use of sheep salt placements, effects of biting flies on elk, habitat selection by elk and sheep, and migration patterns of elk. Forage selection is related to nutritional levels in plants and available minerals. Similarities in elk and sheep seasonal dietary fractions are presented for 142 vascular plant species. Browsing impacts on important woody species are detailed. Management indicator species are designated. Management recommendations are set forth in a manner requisite for ecosystem management.

Keywords: *Cervus elaphus, Populus tremuloides,* ecosystem management, ungulate herbivory, natural mineral licks, salt licks, Tabanid flies

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